ROLE OF REGULAR EXERCISE IN THE TREATMENT OF ABDOMINAL OBESITY IN ADOLESCENT BOYS

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BACKGROUD: Abdominal obesity is a strong risk factor for cardiovascular disease (CVD) and insulin resistance. Currently, the role of regular exercise alone in the treatment of abdominal obesity is unknown in adolescent boys.

OBJECTIVE: The aim of this study was to examine the effect of a 3-month regular exercise alone without calorie restriction on total and abdominal adiposity in overweight adolescent boys. More specifically, the effects of different types of exercise training (aerobic vs. resistance exercise) on total fat, and visceral adipose tissue (VAT) and abdominal subcutaneous adipose tissue (ASAT) were compared.

STUDY DESIGN & METHODS: Thirty overweight adolescent boys (BMI ≥ 95th percentile, 12-18 years, Tanner stage III-V) were randomly assigned to one of three intervention groups: aerobic training (AE, n = 10, 60 min/session, 3 days/week), resistance training (RE, n = 13, 60 min/session, 3 days/week) and no-exercise control group (n = 7). Outcome measurements included waist circumference (WC), total body fat, abdominal AT (VAT and ASAT), cardiorespiratory fitness (CRF) and muscular strength.

RESULTS: Body weight and BMI did not change in both exercise groups ($P > 0.1$), but significantly ($P < 0.05$) increased in the control group. Compared with the control group, a significant ($P < 0.05$) reduction in total fat (kg) was observed in both AE (-2.3 kg) and RE groups (-1.4 kg). Both VAT (kg) and ASAT (kg) were significantly ($P < 0.05$) reduced in the

AE (-9.7% and -6.5%, respectively) and RE groups (-14.5% and -5.2%, respectively). By contrast, both VAT (17.0%) and ASAT (6.2%) were significantly ($P < 0.05$) increased in the control group. Compared with the control group, a significant ($P < 0.05$) improvement in CRF was observed in both exercise groups, and the improvement was greater ($P < 0.05$) in the AE (36.5%) vs. RE (25.8%) groups. Upper and lower body muscular strength were significantly ($P < 0.01$) increased in the RE group (> 30% and 43-50%, respectively) compared with the AE and control groups.

CONCLUSIONS: Regular exercise without calorie restriction, independent of exercise modality, is associated with significant reductions in total and abdominal adiposity and improvements in CRF and muscular strength in previously sedentary overweight adolescent boys.

KEYWORDS: Exercise, abdominal obesity, visceral adipose tissue, subcutaneous adipose tissue, cardiorespiratory fitness, muscular strength, adolescents

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ABBREVIATONS

AE	Aerobic exercise
ASAT	Abdominal subcutaneous adipose tissue
AT	Adipose tissue
BMI	Body mass index
CRF	Cardiorespiratory fitness
CT	Computed tomography
CVD	Cardiovascular disease
DEXA	Dual energy X-ray absorptiometry
FFM	Fat free mass
FM	Fat mass
HDL-C	High-density lipoprotein cholesterol
LDL-C	Low-density lipoprotein cholesterol
METs	Metabolic equivalents
MRI	Magnetic resonance imaging
NHANES	National Health and Nutrition Examination Survey
OGTT	Oral glucose tolerance test
RE	Resistance exercise
RF	Radiofrequency
SM	Skeletal muscle
TG	Triglycerides
T2DM	Type 2 diabetes mellitus
VAT	Visceral adipose tissue
VLDL	Very-low-density lipoprotein
WC	Waist circumference
WHR	Waist-to-hip ratio
WHtR	Waist-to-height ratio
1-RM	1-repetition maximum

1.0 CHAPTER ONE

1.1 INTRODUCTION

The prevalence of childhood obesity has been increasing at an alarming rate (1, 2). The rates of childhood obesity have more than tripled during the past three decades, currently affecting one in three children and adolescents (1, 3, 4). Childhood obesity is a leading public health concern since it is a strong risk factor for many co-morbid conditions such as non-alcoholic fatty liver disease (5), sleep apnea, insulin resistance, type 2 diabetes mellitus (T2DM) (6-8), and cardiovascular disease (CVD) (9-11). As in adults, emerging evidence now suggests that abdominal adiposity, in particular visceral adipose tissue (VAT), is an independent risk factor for diabetogenic and atherogenic abnormalities in children and adolescents (6, 12). Given the rapid secular increases in waist circumference (WC) among children and adolescents (13-17), and that increased WC carries greater health risks than does body mass index (BMI) (18-20), reduction in abdominal obesity should be a target for intervention to reverse obesity-related health risks in youth.

Although the exact causes of childhood obesity are not fully understood, decreased physical activity is a major factor (21, 22). In adults, a number of well-controlled studies demonstrated that regular physical activity performed for 30-60 min/day, 3-7 days/week, is associated with significant reductions in abdominal adiposity and concomitant improvements in obesity-related health risks in non-dieting men and women (23-28). Despite the overwhelming evidence in adults demonstrating the benefits of regular physical activity alone on the reduction of abdominal obesity, to date very few studies have examined the role of regular physical activity alone as a strategy to reduce abdominal obesity in adolescents. Furthermore, it is unclear as to the optimal exercise modality that should be recommended for the treatment of abdominal obesity in adolescents.

Therefore, the primary purpose of this study was to examine the effects of a 3-month regular exercise program without calorie restriction on total and abdominal adiposity in overweight adolescent boys. More specifically, we compared the effects of aerobic exercise training (AE) vs. resistance exercise training (RE) on total and abdominal adiposity in overweight adolescent boys.

1.2 RATIONALE AND SIGNFICANCE

The current physical activity guidelines for children and adolescents recommend moderate to vigorous physical activity for 60 minutes on most days of the week to improve overall health (29-31). However, more than 60% of adolescents in grades 9-12 do not meet the current physical activity recommendation (32). Furthermore, data from the National Health and Nutrition Examination Survey (NHANES) demonstrate that more than 30% of adolescents aged 12-19 years are physically unfit (33). Studies have shown that in children and adolescents, low levels of leisure-time physical activity (34-36) and/or cardiorespiratory fitness (CRF) (37, 38) are associated with increased abdominal fat, a strong risk factor for many health outcomes (39-41).

Previous studies in adults report that a short-term exercise training (12-16 weeks, 30-60 min/day, 3 days/week) is associated with significant reductions in total and abdominal adiposity (VAT and ASAT) in the absence of weight loss (26-28). To date, only a few studies have examined whether exercise alone is associated with reductions in abdominal adiposity in adolescents. Gutin et al. (42) examined the effects of an 8-month aerobic exercise program (30-40 minutes of moderate to vigorous exercise, 2-5 days/week) in combination with lifestyle education on abdominal adiposity in 80 obese adolescents aged 13-16 years. After the intervention, a significant reduction in VAT was observed in the exercise group (-42.0 cm^3) compared with the lifestyle education alone group (-11.0 cm^3). However, these findings may be confounded by poor attendance (~ 50%) in the exercise group. In regards to the role of resistance exercise in the treatment of abdominal obesity, only one study has examined the effects of a 5-month resistance exercise program (2 sets of 12-15 reps, 3 days/week) on VAT in overweight girls aged 7-10 years (43). In this study, the authors observed significant increases in body weight and fat mass in both exercise and control groups, and changes in VAT were not measured in the control group.

Although a few studies have suggested the benefits of regular exercise in overweight children and adolescents, limited data from randomized controlled studies are available to report the effect of regular exercise alone on total and abdominal adiposity in overweight adolescents. Therefore, the present study examined the effects of regular exercise training (AE vs. RE) without calorie restriction on total and abdominal adiposity as determined by imaging techniques in overweight adolescent boys.

1.3 SPECIFIC AIMS

1.3.1 Primary specific aim

To examine the effect of a 3-month aerobic exercise (AE) vs. resistance exercise (RE) without calorie restriction on total and abdominal adipose tissue (AT) in overweight adolescent boys.

Hypothesis 1)

It was hypothesized that both exercise groups would result in significant reductions in total and abdominal AT [both visceral AT (VAT) and abdominal subcutaneous AT (ASAT)] compared with the control group.

Hypothesis 2)

It was hypothesized that the reductions in total and abdominal AT (both VAT and ASAT) would be greater in response to AE than RE.

1.3.2 Secondary specific aim

To examine the effect of a 3-month AE vs. RE without calorie restriction on cardiorespiratory fitness (CRF) and muscular strength in overweight adolescent boys.

Hypothesis 1)

It was hypothesized that the AE and RE groups would result in a significant improvement in CRF compared with the control group, and that the improvement in CRF would be greater in response to AE than RE.

Hypothesis 2)

It was hypothesized that the AE and RE groups would result in a significant improvement in muscular strength compared with the control group, and that the improvement in muscular strength would be greater in response to RE than AE.

2.0 CHAPTER TWO

2.1 LITERATURE REVIEW

2.1.1 The prevalence of childhood obesity

Data from NHANES (1966-1970 and 1999-2004) indicated that the rates of childhood obesity have more than tripled (from 4.6% to 17.4%) in adolescents aged 12-19 years over the past three decades (1, 4). At present, 34.1% of adolescents aged 12-19 years are either at risk for overweight (BMI $\geq 85^{th}$ percentile) or overweight (BMI $\geq 95^{th}$ percentile) (2). Racial disparities persist in the rate of childhood obesity, such that among boys (12-19 years), Hispanics (40.5%) have a higher prevalence of childhood obesity (BMI $\geq 85^{th}$ percentile) compared with Blacks (32.1%) and Whites (34.5%); among girls (12-19 years), Blacks (44.5%) have a higher prevalence of obesity compared with Hispanics (37.1%) and Whites (31.7%) (2).

Recent studies also indicate that abdominal obesity as measured by WC has substantially increased in children and adolescents (13-17). NHANES indicates that between 1988-1994 and 1999-2004, the prevalence of abdominal obesity [$\geq 90^{th}$ percentile of WC for age and gender (44)] in adolescents (12-17 years) increased significantly from 10.5% to 18.1% in boys and 11.0% to 17.8% in girls (13). Among boys, Hispanics (24.4%) are more likely to be abdominally obese compared with their Black (16.4%) and White (17.5%) peers; among girls

(12-17 years), the rate of abdominal obesity is higher in Hispanics (22.2%) and Blacks (21.2%) compared with their White peers (16.3%) (13).

2.1.2 Measurements of abdominal adiposity

Various tools have been employed to evaluate abdominal adiposity ranging from simple surrogate measures [e.g., WC, waist-to-hip ratio (WHR), or waist-to-height ratio (WHtR)] to sophisticated imaging techniques [e.g., dual energy x-ray absorptiometry (DEXA), computed-tomography (CT), or magnetic resonance imaging (MRI)]. The description of each method is shown below.

2.1.2.1 Anthropometric measurements

Waist circumference (WC)

As in adults (45-47), studies in children and adolescents (18-20) have indicated that WC is significantly associated with cardio-metabolic risk factors such as insulin resistance, dyslipidemia and high blood pressure. In a large number of children and adolescents (n = 1,987, aged 10-14 years), Savva et al. (20) reported that WC was significantly associated with high blood pressure and abnormal lipid concentrations, independent of BMI. Similarly, Lee et al. (19) observed that WC is a strong predictor of insulin resistance in both black and white boys and girls aged 8-17 years, independent of BMI percentile. These observations suggest that measuring WC is important for indentifying children and adolescents with increased risks of developing CVD and metabolic disease.

Although there is no consensus regarding the optimal protocol for measurement of WC, previous studies have used: 1) the midpoint between the lowest rib and the iliac crest, 2) the narrowest point of the abdomen, 3) the umbilicus, 4) the last rib, or 5) the iliac crest (48-50). According to a recent systematic review (50), the most commonly used WC measurement sites in the literature were at the narrowest point of abdomen (30%), at the midpoint between the lowest rib and the iliac crest (29%) and at the umbilicus (27%). In this review, the authors revealed a significant and consistent association between WC and health outcomes in adults across gender and ethnicity independent of WC measurement sites (50). However, it is currently unknown whether the associations between WC and health risks differ by measurement sites in children and adolescents.

It appears that the ability of WC to predict health risk may be explained in part by its strong relationship with abdominal AT. Taylor et al. (51) have previously shown that WC is strongly associated with DEXA-measured trunk fat in both boys (r = 0.84) and girls (r = 0.83) aged 3-19 years. Recently, Lee and colleagues (19) also reported a significant association between WC and VAT (r = 0.88) and ASAT (r = 0.91) after accounting for BMI percentile in children and adolescents. Together, these findings suggest that WC, a surrogate measure of abdominal AT, should be included in a routine clinical setting in addition to BMI to evaluate abdominal obesity and related health risks (18, 19, 48).

Waist-to-hip ratio (WHR)

WHR, as calculated by WC divided by hip circumference, has been traditionally used as an index of regional fat distribution (52). The cutoff points for WHR $\geq$ 0.95 for men and $\geq$ 0.80 for women have been used for identifying health risks in adults (53); however, specific cutoff values of WHR have not been developed for children and adolescents.

WHR values should be interpreted with caution because both obese and lean individuals can have the same or similar WHR values but have significantly different body composition (18). WC is dependent on variations in both VAT and ASAT, whereas hip measurement could be influenced by SAT, skeletal muscle (SM) mass, or bone. Therefore, the alterations in WHR with intervention could be influenced by changes in SM mass and not necessarily alterations in AT. Indeed, some studies (18, 51, 54) have shown that the strength of association between WHR and health markers is significantly weaker than those observed with WC, suggesting the usefulness of WC alone to predict health risks associated with abdominal obesity (52, 55).

Waist-to-height ratio (WHtR)

Studies in adults (46, 56-58) and children and adolescents (10, 20, 59) have shown that WHtR is a simple and effective index for assessing abdominal obesity and numerous health risks. As shown in adults (56, 58), some evidence suggests that WHtR is a better predictor of CVD risks than BMI (20, 60) or WHR (54) in children and adolescents. Savva et al. (20) reported that youth aged 10-14 years with higher WHtR (> 75^{th} percentile, > 0.519 in boys and > 0.509 in girls) were more likely to have a clustering of CVD risk factors such as high blood pressure, triglycerides (TG), total cholesterol, low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) than those with lower WHtR (≤ 75^{th} percentile), independent of gender. Similarly, Maffeis et al. (61) observed that obese children and adolescents [as determined by International Obesity Task Force BMI cut-off values (62)] with higher WHtR (> 0.5) had 12-fold higher odds of having the metabolic syndrome than normal weight youth with lower WHtR (≤ 0.5). As such, WHtR > 0.5 has been suggested as a cutoff point in both adults (63, 64) and children and adolescents (60) to identify those who are at greater risk of abdominal obesity and related health risk. Some suggest the use of WHtR in a routine clinical setting since WHtR takes both WC and height into account for growth in children and adolescents (60).

2.1.2.2 Dual energy X-ray absorptiometry (DEXA)

Differential absorption of x-rays by bone and soft tissue was the basis for the development of single photon absorptiometry to measure bone mineral density (65). DEXA is a readily available method to determine fat and lean body mass in human body composition in addition to bone mineral density (66). The principle of DEXA is based on a different attenuation characteristic of bone, lean tissue and fat (66), reflecting their differences in densities and chemical composition (67).

The accuracy of DEXA measurement is influenced by several factors such as tissue thickness, body weight, or body size (66, 68). Although DEXA-measured trunk fat is strongly correlated with abdominal AT in adults (69, 70) and children (71), DEXA is not able to differentiate abdominal AT into VAT and ASAT (72). Despite these limitations, DEXA is widely used to evaluate total and regional body composition because it is non-invasive, reproducible (coefficient variation: 1% for bone mineral content, 2-3% for total fat) (65) and relatively quick (approximately 10-15 minutes for a whole body scan) (73), and produces a very low dose of radiation (less than 1/100 of the exposure from a standard chest x-ray) (66, 74).

Several studies reported a significant association of DEXA-measured abdominal fat with a cluster of CVD in children and adolescents (10, 75). Teixeira et al. (10) reported that trunk fat mass was significantly associated with TG ($r = 0.16$, $P < 0.05$), LDL-C ($r = 0.18$, $P < 0.05$), and apolipoprotein B ($r = 0.27$, $P < 0.01$) in high school boys and girls aged (13.2 ± 1.6 years old, $n = 159$). Similarly, He et al. (75) demonstrated that higher trunk fat mass is associated with significantly higher blood pressure after accounting for total body fat in boys (*n* = 478, 5-18 years), independent of pubertal stages and ethnicity. These observations support that the DEXA scan is a reliable method for predicting abdominal obesity and related health risks in children and adolescents.

2.1.2.3 Magnetic resonance imaging (MRI)

Imaging modalities such as CT and MRI are criterion methods to study human body composition because these provide accurate quantification of various tissue depots such as SM, AT, and organs (76-80). Although both CT and MRI provide direct visualization of various tissue *in vivo*, MRI has advantages over CT in examining body composition since it does not employ ionizing radiation, thereby allowing for multiple image acquisition, repeated measurements over time and permitting investigation in children and adolescents (77, 80, 81).

MRI technique uses the magnetic properties of hydrogen nuclei (protons), most abundant in the body, and its interaction with radiofrequency (RF) to produce images (66). When the body is placed in a strong magnetic field in MRI system, hydrogen protons (^{1}H) within the body have a high affinity for alignment with the magnetic field (66). When RF is applied 90 degree to the direction of the magnetic field, the nuclei will absolve the energy and change the alignment. When the RF is off, the nuclei release the absorbed energy, lose their alignment and return to their original position. MRI manipulates differences in relaxation time (e.g., the time for the nuclei to release the absorbed energy and return to its original position) of hydrogen protons between AT vs. lean tissue to generate high resolution images (66).

Traditionally, a single MRI image acquired at L4-L5 has been used as a surrogate measure of total VAT and ASAT volume in clinical research (82). However, recently, some studies (83-89) have questioned whether a single image obtained at L4-L5 is the most optimal measurement site for predicting total VAT and obesity-related health risk. Several studies in adults (86-88) have demonstrated that VAT area (cm^2) obtained in the upper abdominal region (e.g., L2-L3, L3, or 5-10 cm above L4-L5) is a stronger correlate of total VAT volume compared with images obtained in the lower abdominal region (e.g., L4-L5 level). Furthermore, Kuk et al. (90) and Shen et al. (84) noted that VAT area (cm^2) obtained in the upper abdominal region (e.g., L1-L3 or 10cm above L4-L5) is more strongly associated with metabolic syndrome (90) and obesity-related health risks such as TG, HDL-C, glucose, insulin and blood pressure (84) than VAT measure at L4-L5. These findings suggest that a single image obtained in the upper level of the abdomen (e.g., L1-L3) may be a better measurement site for predicting total VAT and cardio-metabolic risks than the traditional measurement site (L4-L5 level). However, whether the measurement sites of VAT influences the prediction of health risk is currently unknown in children and adolescents.

In summary, abdominal obesity is a strong risk factor for CVD and metabolic abnormalities independent of total adiposity. Although anthropometric measures (WC and WHtR) and DEXA are readily available methods, these are unable to differentiate between VAT and ASAT. By contrast, imaging techniques such as MRI provide accurate quantification of VAT and ASAT. The advantages and disadvantages of various techniques are summarized in **Table 1**.

Table 1. Advantages and disadvantages of abdominal adiposity measurements

Measurements	Advantages	Disadvantages
Anthropometry	Simple and inexpensive Feasible in large population based studies	No uniform measurement sites Unable to distinguish VAT and SAT
DEXA	Low radiation Fast data acquisition Quantify FM and FFM	Body weight and size limits Unable to distinguish VAT and SAT
CT	High accuracy and reproducibility Fast data acquisition Quantity VAT, SAT and SM	Expensive Radiation exposure Not readily available
MRI	High accuracy and reproducibility Quantity VAT, SAT and SM	Expensive Time-consuming in data analysis Not readily available

2.1.3 Abdominal adiposity and health risks

Abdominal adiposity is divided into two distinct anatomical compartments: VAT (or intra-abdominal fat) and ASAT. VAT is located in the abdominal cavity around the visceral organs (91, 92) and can be sub-divided into retroperitoneal (perirenal depot) and intraperitoneal (mesenteric and omental depots) compartments via anatomical landmarks such as the colon, aorta, and kidneys (91). ASAT is located underneath the skin layers. As shown in **Figure 1**, ASAT can be further sub-divided into superficial and deep ASAT using the fascial plane (91-93).

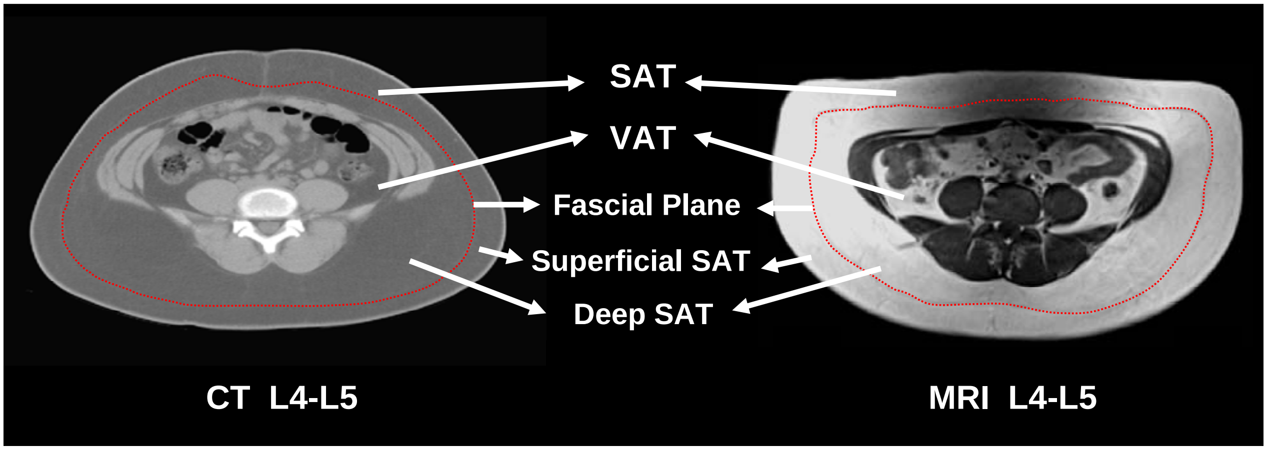


Figure 1. Cross-sectional image of the abdomen (L4-L5) as measured by CT and MRI

The associations between VAT and health outcomes have been extensively examined in both adults (93-99) and children and adolescents (6, 39-41, 100, 101). With few exceptions, the majority of cross-sectional studies in adults (94-97) have demonstrated that elevated levels of VAT, as determined by CT or MRI, is strongly associated with the development of CVD and metabolic abnormalities independent of ASAT. Ross et al. (94, 95) have shown that VAT was significantly associated with glucose disposal as determined by the hyperinsulinemic euglycemic-clamp technique in men (r = -0.40) and women (r = -0.42), and these observations remained significant after controlling for ASAT in both studies (94, 95). When subjects were divided into high (> 60th percentile) or low level (< 40th percentile) of VAT or ASAT, individuals with high level of VAT were significantly more likely to have higher 2-h OGTT (oral glucose tolerance test) glucose concentrations and lower glucose disposal levels than those with lower levels of VAT, whereas no significant effects of ASAT on these associations were observed in both studies (94, 95). Some longitudinal studies also confirmed that elevated level of VAT significantly predicts the increased risks of development of T2DM (98) and all-cause mortality (99) in adults.

As in adults, it is well established that VAT is significantly associated with increased health risk in children and adolescents (39-41). Owens et al. (39) reported that MRI-determined VAT was significantly associated with adverse blood profiles including TG (r = 0.27), total cholesterol (r = 0.27), LDL-C (r = 27), HDL-C (r = -0.26), and systolic blood pressure (r = 0.30) in obese adolescents aged 13-16 years. Similarly, in a recent study by Taksali et al. (41), a high level of VAT was significantly associated with higher levels of TG and 2-h OGTT glucose concentrations and lower levels of HDL-C, leptin, and insulin sensitivity in obese adolescents aged 13-15 years, and these findings remained significant even after accounting for age, gender, and ethnicity. They also observed that obese adolescents with a higher proportion of VAT relative to lower ASAT were 5 times more likely to have metabolic syndrome than those with a lower proportion of VAT relative to high ASAT (41), suggesting that the increase in VAT conveys greater risks of CVD and metabolic syndrome complications in adolescent age group.

Although the mechanisms by which VAT is an independent predictor of these risk factors are not fully understood, "Portal Theory" (102) has long been used to explain the causative links between VAT and metabolic abnormalities. Visceral adipocytes are more metabolically active compared to subcutaneous adipocytes, and secrete free fatty acids (FFAs) directly into the portal vein (102-104). The increased amounts of FFAs released into the portal circulation are directly exposed to the liver, which may lead to increases in hepatic gluconeogenesis, very-low-density lipoprotein (VLDL) production, and impaired insulin clearance, contributing to the development of insulin resistance (102-104). Another possible mechanism is that VAT is an endocrine organ that secretes proinflammatory biomarkers such as tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), plasminogen activator inhibitor (PAI-1), and adiponectin, which play a significant role in the development of diabetogenic and/or atherogenic abnormalities (92, 104-

106). Some suggest that adipocytokines such as IL-6 and PAI-1 are secreted in higher amounts by visceral adipocytes than by subcutaneous adipocytes (104) and positively correlated with insulin resistance in adults (107, 108) and adolescents aged 12-14 years (109).

Taken together, there is considerable evidence to support that the excessive accumulation of abdominal AT, in particular VAT, conveys the increased health risk, independent of total adiposity, in children and adolescents (39-41). Effective intervention strategies are needed to reduce abdominal AT in order to prevent obesity-related comorbid conditions in youth.

2.2 PHYSICAL ACTIVITY AND ABDOMINAL OBESITY

2.2.1 Leisure-time physical activity

The rapid increase in childhood obesity in recent years parallels a concomitant decline in physical activity level in children and adolescents (22). The recent national Youth Risk Behavior Survey (32) reported that only one in three (34.7%) US students are meeting the current physical activity recommendations of 60 minutes or more of physical activity on five or more days of the week, and 24.9% of students do not participate in 60 minutes of physical activity on any day of the week. The prevalence of physical inactivity is higher among girls than boys; and among Blacks and Hispanics than Whites (32).

The relationship between physical activity and abdominal obesity has been widely examined and the summary of their findings are shown in **Table 2**. With few exceptions, the majority of studies demonstrated that decreased leisure time physical activity or increased sedentary behavior (e.g., TV watching/video games) is associated with abdominal obesity as evaluated by either WC or imaging techniques. In a large sample of 12-year old French adolescents (n = 2,714), Klein-Platat et al. (110) reported that although WC is inversely associated with structured physical activity (outside school, > 140 min/week), and positively associated with sedentary activities (e.g., TV watching), structured physical activity is independently associated with a significantly lower WC after accounting for BMI and sedentary activities. They also observed that the effect of structured physical activity on WC was greater in overweight adolescents (BMI > 90th percentile) compared with normal weight adolescents

(BMI < 90th percentile) (110). Using accelerometry, Ortega and colleagues (111) reported that decreased time spent in vigorous physical activity (> 6 metabolic equivalents, METs) is independently associated with increased WC in a large number of Swedish children and adolescents (*n* = 1,174) after controlling for confounding factors (e.g., time spent in sedentary activities, sexual maturation and birth weight). In this study (111), children and adolescents in the lowest tertile of vigorous activity group had 4-fold higher odds of being overweight, and 2-fold higher odds of having a high WC, and these observations remained significant after controlling for sedentary activities. Conversely, total amount of physical activity alone was not associated with a high-risk WC. These findings are consistent with other studies demonstrating that vigorous physical activity is a stronger correlate of WC (112) and DEXA-measured abdominal adiposity (113) than low-moderate intensity activities and suggest that appropriate level of vigorous physical activity should be encouraged to prevent abdominal obesity in children and adolescents.

To date, there have been only three studies (34-36) wherein the relationship between habitual physical activity and VAT distribution was measured by imaging techniques in children and adolescents. Among these (34-36), only Saelens and colleagues (35) employed both accelerometery and questionnaires to evaluate current physical activity levels. They reported that 7-day accelerometery measured total physical activity level, but not self-reported physical activity, was significantly related to VAT, ASAT and total adiposity in 8-year-old children. Furthermore, the relation between accelerometer-measured total physical activity and VAT remained significant even after controlling for total adiposity. By contrast, no significant effects of sedentary activities or dietary intake on VAT were observed in this study.

In pediatrics, limited evidence, wherein physical activity was directly measured by accelerometery, suggests that increased physical activity is associated with lower abdominal obesity, and that increased time spent in vigorous physical activities (> 6 METs) is independently associated with a lower WC and VAT. The fact that the positive relationships between increased sedentary activities (e.g., TV watching and video games) and abdominal obesity did not remain significant (111) after accounting for vigorous physical activity level has an important public health message, and suggest that high intensity physical activity should be implemented in daily living for the prevention of abdominal obesity in children and adolescents. However, further studies are needed to examine the minimal and optimal level of physical activity required for the reduction of abdominal obesity in youth.

2.2.2 Cardiorespiratory fitness (CRF) and abdominal obesity

Cardiorespiratory fitness (CRF) is a stronger predictor of many health outcomes than self-reported physical activity and tends to be less prone to bias and misclassification (114). Although CRF is influenced by non-modifiable factors (e.g., genetics, gender, and age), changes in CRF are largely influenced by recent physical activity patterns (115).

Recent NHANES (1999-2002) data indicated that approximately 33.6% US adolescents aged 12-19 years are physically unfit as evaluated by submaximal treadmill test (116). In contrast to self-reported PA, the prevalence of low fitness (< 20th percentile) is similar between boys and girls, but is higher in Blacks and Hispanics compared with their White peers. This has large consequences since unfit adolescents (< 20th percentile) are 2 to 4 times more likely to be overweight or obese than those with higher fitness levels (≥ 20th percentile). Moreover, adolescents in the lowest fitness category had a higher prevalence of metabolic syndrome and hypercholesterolemia, and higher WC than those in the higher fitness groups (116).

In a large sample of Spanish adolescents aged 13-18 years (*n* = 2,859), Ortega et al. (117) reported that in both boys and girls, CRF (20 m shuttle run test) or sedentary activity is independently associated with WC. When subjects are divided into normal-weight and overweight groups, CRF is inversely associated with BMI-adjusted WC in overweight adolescents, but not in normal-weight adolescents. No significant associations between sedentary activity and BMI-adjusted WC were observed for either normal-weight or overweight adolescents. The fact that leisure time physical activity, as evaluated by questionnaire, was not independently associated with WC suggests that CRF may be a stronger predictor of abdominal obesity than habitual activity habits, in particular in overweight children and adolescents.

To the best of our knowledge, there are only three studies wherein the influence of CRF on abdominal fat was measured by imaging techniques in children and adolescents (**Table 3**). We previously demonstrated that after accounting for age, gender and pubertal status, CRF assessed by maximal treadmill test is inversely associated with VAT (r = -0.43, r = -0.68) and ASAT (r = -0.52, r = -0.72) and WC (r = -0.43, r = -0.65) in both black and white youth aged 8-17 years (37). Within the same BMI category (e.g., BMI < 85^{th} and BMI $\geq$ 85^{th}), the moderate and high CRF groups have significantly lower VAT and ASAT compared with the low CRF group. Furthermore, we observed a significant CRF by BMI group interaction, indicating that the beneficial effect of CRF on VAT and ASAT was greater in children and adolescents with higher BMI ($\geq$ 85^{th} percentile) than in those with lower BMI (< 85^{th} percentile). These observations are in agreement with adult findings (118-120), demonstrating that higher CRF is associated with lower WC (118-120) and abdominal fat (118, 120), independent of BMI.

Similarly, using a multi-slice MRI technique (spanning from L1 to L5), Winsley et al. (38) reported that in White children (13.5 ± 0.5 years), CRF is inversely associated with VAT volume (L) in both boys (r = -0.43) and girls (r = -0.45). However, these observations (37, 38) differ from a similar study by Eliakim et al. (121) who have shown that CRF is associated with ASAT (r = - 0.47, P < 0.05), but not with VAT (r = - 0.14, not significant) in late-puberty non-overweight girls (15-17 years of age).

Given that low CRF is a strong predictor of CVD and metabolic risks (121-123) and that higher CRF is significantly associated with lower VAT (37, 38) in children and adolescents, consideration should be given in the routine clinical settings to identify youth with lower CRF in addition to traditional CVD risk factors. Furthermore, given that CRF in adolescents tracks well into adulthood (124), strategies to improve CRF should be implemented during early childhood.

2.2.3 Effects of aerobic exercise training on abdominal obesity

Recent report (125) demonstrates that although VAT reduction is significantly associated with the amount of weight reduction during aerobic training, a significant VAT loss can occur without substantial weight loss. Indeed, using whole body MRI, several intervention studies demonstrate that a short-term (12-16 weeks) aerobic exercise alone is associated with significant reductions in total, ASAT and VAT in the absence of changes in body weight or BMI in adult men and women (26-28).

To the best of our knowledge, there are six randomized controlled studies wherein the effect of aerobic exercise on abdominal fat was examined in children and adolescents (**Table 4**). Owens et al. (126) demonstrated that in obese children (7-11 years), a 4-month aerobic exercise program (5 times/week, 40 min/day) in combination with games (basket ball, dodge ball and tag) was associated with significant reductions in total fat (-0.8kg vs. 0.9kg) and ASAT (-16.2 cm^3 vs. 48.9 cm^3), and lower increases in VAT (1.3 cm^3 vs. 20.9 cm^3) compared with the controls, despite increases in body weight likely attributed to the normal growth. These findings are in agreement with the observations by Eliakim et al. (127), who demonstrated that in 38 non-obese previously sedentary boys (15-17 years), a 5-week endurance type training program (5 times/week, 120-150 min/day) without weight loss is associated with significant reductions in ASAT (-1.8% vs. 1.8%) and attenuated the increase in VAT (-0.2% vs. 4.5%) compared with the controls.

Gutin et al. (42) reported that obese adolescents (13-16 years of age) who participated in an 8-month exercise program in combination with lifestyle education achieved greater reductions in total fat (-3.6% vs. 0.2%), VAT (-42.0 cm^3 vs. -11.0 cm^3) and ASAT (-69.7 cm^3 vs. 40.4 cm^3) than subjects who participated in lifestyle education alone. In this study, the authors initially sought to examine the effects of exercise intensity [moderate (55-60% VO_{2peak}) vs. high-intensity (75-80% VO_{2peak})] on visceral adiposity, however this study was hampered by poor attendance (51% and 56% in the moderate- and high-intensity group) and the lack of compliance to the prescribed exercise regimens. Thus, the role of exercise intensity on abdominal fat is still unknown in children and adolescents.

Recently, Barbeau et al. (128) examined the influence of a 10-month aerobic type of exercise program without calorie restriction on abdominal adiposity assessed by WC and MRI in a large sample of Black girls (*n* = 201). In this study, an after-school daily physical activity program of 35 minutes of moderate-vigorous exercise in addition to other physical activities was associated with attenuated age-related increases in VAT (0.8 cm^3 vs. 16.1 cm^3) and ASAT (65.2 cm^3 vs. 130.0 cm^3), and a lower WC (1.4 cm vs. 2.9 cm) by comparison to the controls. Further, those who maintained higher attendance rate (≥ 2 days/week) and higher heart rate (≥ 150 beats/min) during the exercise intervention experienced greater reductions in total adiposity and BMI, suggesting the importance of participating in higher intensity aerobic exercise in the treatment of childhood obesity. Taken together, these findings (42, 126-128) provide evidence that engaging in regular aerobic types of exercise is associated with reductions in total fat and has a protective effect on age-associated increases in VAT in children and adolescents.

2.2.4 Effects of resistance exercise training on abdominal obesity

Although aerobic exercise has been traditionally employed in the treatment of childhood obesity, carefully supervised resistance training is also beneficial for improving muscular strength, muscular endurance, bone mineral density, body composition and mental health in children and adolescents (129-131). Recent evidence suggests that progressive resistance training or in combination with aerobic exercise (e.g., circuit training) is associated with significant improvement in insulin sensitivity without changes in total adiposity in previously sedentary overweight children and adolescents (132, 133). However, currently, very little is known about the influence of resistance training alone on the abdominal fat reduction in children and adolescents, or about whether changes in abdominal fat may mediate the improvements in health outcomes.

To the best of our knowledge, we are aware of only four intervention studies wherein the effect of resistance exercise without calorie restriction on abdominal obesity was examined in children and adolescents (**Table 5**). In a randomized controlled study, Benson et al. (134) reported that after an 8-week high-intensity progressive resistance training (2 days/week, 2 sets of 8 repetitions in 11 exercises), WC (-0.8 cm vs. 0.5 cm) and percent body fat (-0.3% vs. 1.2%)

was significantly decreased in the training group by comparison to the controls in normal-weight and overweight children (12.2 ± 1.3 years). Although the average reduction in WC was modest (-0.8 cm) in the training group, the reduction in WC was greatest in those with the greatest upper body strength gains and decreases in body fat mass. Similarly, using a randomized crossover design, Watts et al. (135) observed a significant reduction in DEXA-measured abdominal fat (-0.6 kg) and trunk fat (-0.7 kg) in response to a progressive 8-week resistance training combined with aerobic training in comparison to the control condition in obese adolescents (14.3 ± 1.5 years).

At present, there has only been one study that has examined the influence of resistance training alone on VAT in children and adolescents. Treuth et al. (43) observed significant increases in total and ASAT, with no changes in VAT after a 5-month resistance training in obese pre-pubertal girls (7-10 years). However, given that VAT did not increase significantly despite the fact that these children gained significant body weight (4 kg vs. 2.9 kg in the exercise vs. control groups, respectively) and total fat mass (1.5 kg vs. 1.0 kg in the exercise vs. control groups, respectively) suggests that regular resistance exercise may have attenuated the age-related increases in VAT in the treatment group (43). However, because this study did not measure abdominal fat in the control group, the role of resistance exercise in the treatment and prevention of visceral adiposity is unclear.

2.3 SUMMARY

Obesity, in particular abdominal obesity, has substantially increased over the past two decades in children and adolescents (13). The epidemic rate of childhood obesity parallels the decline in physical activity level in children and adolescents (22). In adults, evidence from a number of well-controlled studies show that regular exercise alone, performed for 30-60 min/day $\geq$ 3 days a week, is associated with significant reductions in total and VAT in men and women (23-28). Currently, it is unknown whether this remains true in overweight adolescent boys. Uncertainties also exist as to the optimal exercise modality that should be recommended for the treatment of abdominal obesity in adolescent boys.

Table 2. Associations between leisure-time physical activity and abdominal obesity

References	N	Age (years) Boys/Girls	BMI or BW	Methods: PA	Methods: Abdominal obesity	Main findings
Roemmich et al. (34)	29 boys (14 pre/14 pubertal) 31 girls (13 pre/18 pubertal)	10.9/13.4 10.2/12.8	34.8/52.0 kg 34.7/51.2 kg	7-day PA recall	MRI	In boys but not in girls, TPA and VPA (10 METs) were inversely associated with VAT (*r* = -0.39 and -0.43, respectively).
Saelens et al. (35)	21 boys 21 girls	8	21.5 kg/m^2 23.1 kg/m^2	Accelerometer (7 days) Questionnaire	MRI	Accelerometer-measured TPA, but not self-report PA, was significantly associated with VAT (*r* = -0.43) and this remained significant after accounting for total fat.
Stallmann-Jorgensen et al. (36)	339 Whites (169 boys/170 girls) 322 Blacks (163 boys/159 girls)	16.2/16.0 16/0/16.3	22.5/21.9 kg/m^2 23.4/25.0 kg/m^2	24-h PA recall	MRI	Independent of race, self-report PA variables were not independently associated with VAT.
Dencker et al. (113)	124 boys 101 girls	9.8 9.8	34.8 kg 34.8 kg	Accelerometer (4 days)	DEXA	Time spent in VPA (>6 METs) and MPA~VPA (3~6 METs) was associated with total adiposity (%) and abdominal fat, and these relationships were stronger for VPA than MPA.
Klein-Platat et al. (110)	1357 boys 1357 girls	12.0 12.0	19.0 kg/m^2 19.1 kg/m^2	Questionnaire	WC	WC was inversely associated with structured PA (>140 min/wk) and positively associated with SED independent of gender. Structured PA was inversely associated with WC after accounting for SED in both boys and girls.
Ortega al. (111)	557 children (269 boys/288 girls) 517 adolescents (238 boys/279 girls)	9.5/9.5 15.6/15.5	33.4/33.7 kg 64.2/57.8 kg	Accelerometer (4 days)	WC	Youth with a low level of VPA (>6 METs) had two-fold higher odds of having a high WC. Although birth weight and TV viewing were associated with higher odds of having a high WC, these findings were attenuated once VPA or TPA was controlled.
Butte et al. (136)	424 non-overweight (194 boys/230 girls) 473 overweight (247 boys/226 girls)	10.7/10.7 11.1/10.9	41.9/38.9 kg 69.6/63.7 kg	Accelerometer (3 days) Questionnaire	WC	WC was weakly but significantly associated with SED (*r* = 0.07) and negatively with LPA (*r* = -0.08) after controlling for age, gender, and percent fat in Hispanic youth.

Continued

References	N	Age (years)	BMI or BW	Methods		Main findings
		Boys/Girls		PA	Abdominal obesity	
Ekelund et al. (112)	1,008 children (504 boys/504 girls) 738 adolescents (334 boys/404 girls)	9.7/9.6 15.5/15.5	33.3/32.9 kg 62.4/55.8 kg	Accelerometer (4 days)	WC	Accelerometer-measured PA variables were not associated with WC after controlling for age, gender and study location.
Ortega et al. (117)	1,445 boys 1,403 girls	15.4 15.4	21.8 kg/m^2 21.5 kg/m^2	Questionnaire	WC	SED, but not leisure time PA, was associated with WC independent of gender. SED explained 10% of the variance in WC in boys and 18% in girls.
Hussey et al. (137)	84 boys 140 girls	7-10	16.9 kg/m^2 16.7 kg/m^2	Accelerometer (4 days)	WC	Significant relationships between accelerometer-measured PA and WC were observed in boys (MPA, r = -0.47; VPA, r = -0.31), but not in girls.
Kelishadi et al. (138)	2,248 boys 2,563 girls	12.1 12.0	18.3 kg/m^2 18.7 kg/m^2	Questionnaire	WC	No differences in WC between the PA tertile groups in Iranian boys and girls.
Duncan et al. (139)	536 boys 579 girls	5-12	European: 17.2 kg/m^2 Polynesian:19.7 kg/m^2 Asian: 17.2 kg/m^2 Others: 17.0 kg/m^2	Pedometer (5 days)	WC	Youth with high WC ($\geq$ 80th percentile) had significantly lower weekday and weekend step counts compared with youth with normal WC (< 80th percentile).
Garnett et al. (16)	221 boys 215 girls	7-8	NA	Questionnaire	WC	VPA level at baseline was not associated with abdominal obesity measured at 5 yr follow-up.

BMI, body mass index; BW, body weight; CT, computed tomography; LPA, low intensity PA; MPA, moderate intensity PA; MRI, magnetic resonance imaging; NA, not available; PA, physical activity; SED, sedentary activities; TPA, total PA; WC, waist circumference; VPA, vigorous PA

Table 3. Associations between cardiorespiratory fitness (CRF) and abdominal obesity

References	N	Age	BMI (kg/m^2)	Methods: CRF	Methods: Abdominal obesity	Main findings
Lee & Arslanian (37)	58 boys 55 girls	8-17	23.4 23.7	Treadmill	CT WC	CRF was associated with VAT (*r* = -0.43 and *r* = -0.68) and ASAT (*r* = -0.52 and *r* = -0.72) and WC (*r* = -0.43 and *r* = -0.65) in both Blacks and Whites, respectively.
Winsley et al. (38)	30 boys 22 girls	13.7 13.5	19.2 21.5	Treadmill	MRI	CRF was inversely associated with VAT volumes (L1~L5) in boys (*r* = -0.43) and girls (*r* = -0.45).
Eliakim et al. (121)	44 non-obese girls	15-17	22.5	Cycle	MRI	CRF was related with ASAT (*r* = -0.47) and total abdominal AT (*r* = -0.46), but not with VAT.
Carnethon et al. (116)	3,110 adolescents	12-19	boys/girls 22.8/23.3	Treadmill	WC	Youth with low CRF (< 20th) had higher WC compared to those with moderate (20th -59th) and high CRF ($\geq$60th) in both boys (84.7 cm >78.8 cm > 76.6 cm) and girls (82.9 cm > 78.8 cm > 76.2 cm).
Ekelund et al. (112)	1,008 children (504 boys/504 girls) 738 adolescents (334 boys/404 girls)	9.7/9.6 15.5/15.5	17.4/17.2 20.8/20.8	Cycle	WC	CRF was significantly associated with WC (*r* = -0.20) and this remained significant after controlling for age, gender, study location and accelerometer-measured total PA.
Klasson-Heggebø et al. (123)	2,108 children (1,042 boys/1,066 girls) 1,964 adolescents (926 boys/1,038 girls)	9.7/9.6 15.5/15.5	17.3/17.2 20.6/20.8	Cycle	WC	In children, CRF explained 20-26% of the variance in WC. In adolescents, CRF explained 17% and 9% of the variance in WC in boys and girls, respectively.
Ortega et al. (117)	1,445 boys 1,403 girls	15.4 15.4	21.8 21.5	20-m shuttle run	WC	CRF explained 13% and 16% of the variance in WC in boys and girls, respectively.
Shaibi et al. (140)	91 boys 72 girls	11.3 11.1	27.4 28.6	Treadmill	WC	CRF was inversely associated with WC (*r* = -0.53), however this did not remain significant after controlling for age, gender, fat mass and fat free mass.
Psarra et al. (141)	477 boys 441 girls	8.8	17.2	20-m shuttle run	WC	Children with the lowest fitness (1st quartile) at baseline have 4.3-fold increased risk of maintaining high WC at 2 yr follow-up.
Hussey et al. (137)	84 boys 140 girls	7-10	16.9 16.7	20-m multistage run	WC	WC was inversely associated with CRF (*r* = -0.50, *r* = -0.33 in boys and girls, respectively).

ASAT, abdominal subcutaneous adipose tissue; AT, adipose tissue; BMI, body mass index; CRF, cardiorespiratory fitness; PA, physical activity; WC, waist circumference; VAT, visceral adipose tissue

Table 4. Effects of aerobic exercise training alone on abdominal obesity

Reference	Subjects	Age (years)	Treatment	BW or BMI	Duration	Protocol	Δ BW or BMI	ΔBF (%)	Δ WC (cm)	Δ VAT	ΔASAT
Randomized controlled trials											
Owens et al. (126)	25 boys, 49 girls	7-11	Control (n=39) Exercise (n=35)	56.9 kg 57.5 kg	4 mo	5 days/wk, 40 min/day, 70-75% MHR treadmill, cycle, games	2.0 kg* 1.1 kg*	0.0 -2.2*†	NA	20.9 cm^3*† 1.3 cm^3	48.9 cm^3*† -16.2 cm^3
Eliakim et al. (127)	38 boys	15-17	Control (n=18) Exercise (n=20)	66.2 kg 61.0 kg	5 wk	5 days/wk, ~2.5h/day running, basketball, aerobic dance	0.6 kg 0.8 kg	0.4 -0.3	NA	4.5%*† -0.2%	1.8%*† -1.8%*
Gutin et al. (42)	26 boys, 54 girls	13-16	Control (LSE) (n=38) Exercise,~60%VO_{2peak} (n=21) Exercise, ~80%VO_{2peak} (n=21)	White boys: 95.2 kg Black boys: 100.2 kg White girls: 88.5 kg Black girls: 94.8 kg	8 mo	2-5 days/wk, EE: 250 kcal/day 55-80% of VO_{2peak} treadmill, cycle, stepper	NA	0.2 -3.6† (groups combined)	NA	-11.0 cm^3 -42.0 cm^3 † (groups combined)	40.4 cm^3 -69.7 cm^3 (groups combined)
Barbeau et al. (128)	201 Black girls	8-12	Control (n=83) Exercise (n=118)	20.9 kg/m^2 20.9 kg/m^2	10 mo	daily after school program 80 min/day basketball, aerobics, etc.	1.3 kg/m^2† 0.7 kg/m^2	0.3 -1.1†	2.9 1.4	16.1 cm^3† 0.8 cm^3	129.8 cm^3† 65.2 cm^3
Eliakim et al. (121)	44 girls (mixed race)	15-17	Control (n=22) Exercise (n=22)	58.3 kg	5 wk	2-h daily endurance type training	NA	-1.7* NA	NA	0.2% 0.3%	0.1% 0
Kim et al. (142)	26 boys (Korean)	17.0	Control (n = 12) Exercise (n= 14)	90.4 kg 89.7 kg	6 wk	Jump rope exercise 5 days/wk, 40 min/day	0.0 kg -2.2 kg*	-1.5 -2.2*	-1.8 -2.5*	NA	NA
Non-randomized controlled trials											
Nassis et al. (143)	19 girls	9-15	Exercise	67.9 kg	12 wk	3 days/wk, 40 min/day running, steps, stair climbing, team sports	0.4 kg	-0.7	1.1*	2.5 cm^2 (estimated)	NA
Watts et al. (144)	6 boys, 8 girls	8.9	Exercise	62.8 kg	8 wk	3 days/wk, 60 min/day dodge ball, tag, jogging (heart rate: 140-180 bpm)	-0.3 kg	NA	0	NA	NA
Kelishadi e tal. (145)	19 boys 16 girls	12-18	Exercise	57.1 kg	6 wk	3 days/wk, 60 min/day running, playing games	-2.4 kg*	-1.6*	-2.2*	NA	NA

Continued

Reference	Subjects	Age (years)	Treatment	BW or BMI	Duration	Protocol	Δ BW or BMI	ΔBF (%)	Δ WC (cm)	Δ VAT	Δ ASAT
Non-randomized controlled trials											
Lazaar et al. (146)	213 boys 212 girls	6-10	Non-obese Control Obese Control Non-obese Exercise Obese Exercise	boys/girls 23.5/24.0 kg 33.7/33.5 kg 23.9/24.5 kg 35.5/32.0 kg	6 mo	School based PA, 2 days/wk, 60 min/day	boys/girls 0.9/0.7 kg 0.5/0.6 kg 0.7/0.7 kg 0.4/0.7 kg	NA	boys/girls 0.3/1.3 0.6/2.2 -0.1/-1.9* -0.4/-2.1*	NA	NA
Resnicow et al.(147)	123 girls	12-16	Moderate intensity (MI, n=70) High intensity (HI, n=53)	88.0 kg 84.2 kg	6 mo	MI: 6 sessions HI: 24~26 sessions	1.5 kg 0.7 kg	0.7 -0.4	1.9 -0.1	NA	NA
van der Heijden et al. (148)	17 boys 12 girls	15.1	Obese Exercise (n=15) Lean Exercise (n=14)	91.7 kg 57.2 kg	12 wk	2 days/wk, 30 min/day ≥ 70% of VO_{2peak} treadmill, elliptical, cycle	-0.5 kg 0.8 kg	-1.0* 0.3	NA	-5.1 cm^2* no change	no change no change

ASAT, abdominal subcutaneous adipose tissue; BMI, body mass index; BF, body fat; BW, body weight; EE, energy expenditure; LSE, lifestyle education; MHR, maximal heart rate; NA, not available; VAT, visceral adipose tissue; WC, waist circumference; Δ, Change score
*Significantly different from baseline within each group ($P < 0.05$)
†Significantly different from controls ($P < 0.05$)

Table 5. Effects of resistance exercise training alone on abdominal obesity

References	Subjects	Age (years)	Treatment	BW (kg)	Duration	Protocol	Δ BW (kg)	ΔBF (%)	Δ WC (cm)	Δ VAT (cm^2)	Δ SAT (cm^2)
Benson et al. (134)	46 boys, 32 girls	10-15	RCT Control (n=41) Exercise (n=37)	51.9 56.9	8 wk	2 days/wk, 80% of 1RM 2 sets, 11 exercises	2.0 1.5	1.2 -0.3†	0.5 -0.8†	NA	NA
Watts et al. (135)	9 boys, 10 girls	14.3	Crossover study Untrained vs. trained	96.4	8 wk	Resistance + cycling 3 days/wk, 60 min/day 55-70% of 1RM	0	-0.6	0.6	NA	NA
Treuth et al. (43)	22 girls	7-10	NRCT Control (n=11) Exercise (n=11)	29.1 46.6	5 mo	3 days/wk, 50% of 1RM 2 sets, 12-15 reps, 7 exercises	2.9* 4.0*	1.0 kg* 1.5 kg*†	NA NA	NA 1.5	NA 16.0*
Bell et al. (133)	8 boys, 6 girls	12.7	Exercise	80.6	8 wk	Resistance + cycling 3 days/wk, 55-65% of 1RM 2 sets, 10 exercises	0.6	-0.6 kg	-2.3*	NA	NA

ASAT, abdominal subcutaneous adipose tissue; BMI, body mass index; BF, body fat; BW, body weight; NA, not available; NRCT, non-randomized controlled study; RCT, randomized controlled study; VAT, visceral adipose tissue; 1RM, 1 repetition maximum; Δ, Change score.
*Significantly different from baseline within each group ($P < 0.05$)
†Significantly different from controls ($P < 0.05$)

3.0 CHAPTER THREE

3.1 METHODS

3.1.1 Subjects

Overweight adolescent boys [BMI ≥ 95th percentile for age and gender (149)] were recruited from the greater Pittsburgh area via newspaper advertisements, flyers posted in the city public transportation, and posters placed on the University of Pittsburgh campus and in the Weight Management and Wellness Clinic at Children's Hospital of Pittsburgh (CHP). Subjects were included if they were 12-18 years of age, Tanner stages III-V, abdominally obese (age-, sex-, and race-specific WC ≥ 75th percentiles) (44), non-smokers, and sedentary (no structured physical activity > 2 times per week for past 3 months). Subjects were excluded based on the following exclusion criteria: chronic diseases (e.g., asthma, diabetes, psychiatric disorder, or syndromic obesity) and medications which may impact body composition. Subjects who experienced significant weight change (approximately ± 5 kg) over the past 3-month were also excluded (**Table 6**).

Table 6. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
• 12-18 years of age in Tanner stages III-V • BMI ≥ 95^{th} percentile for age and gender • WC ≥ 75^{th} percentile for age and gender • Non-smokers • Sedentary	• Chronic diseases - Asthma - Diabetes - Psychiatric disorders - Hypertension - Syndromic obesity • Medications • Significant weight change (± 5 kg)

3.1.2 Informed consent and screening procedures

After an initial phone screening, eligible subjects and their parents were invited for an informed consent/assent and screening visit in the Pediatric Clinical Transitional Research Center (PCTRC) at CHP. During this visit, subjects and their parents were fully informed about the nature of the research, risks and potential benefits of study participation, and rights as a research subject. Once the subjects and their parents agreed to participate and the consent form was signed by both, complete medical and physical examination were performed by a certified nurse practitioner. The standard physical examination included measurements of height, weight, WC, Tanner stage, medical history, and physical activity level. This procedure took approximately 40-45 minutes to complete.

3.1.3 Nutrition education session and dietary run-in period

After the initial screening and determining eligibility, subjects and their parents participated in a nutrition education session. During this session, healthy food selection, preparation (e.g., fruits, vegetables, whole grains, and/or low-fat foods) and a healthy weight maintenance diet (55-60% carbohydrate, 15-20% protein and 25-30% fat) according to American Heart Association (AHA) dietary recommendations (150-152) were introduced by nutritionist. In addition, subjects were instructed to record amounts (portion sizes) and types of self-selected foods consumed throughout the days (i.e. breakfast, lunch, dinner, and snacks) (**APPENDIX A**). Daily energy requirement (kcal/day) was prescribed according to Harris-Benedict equation (**Formula 1)** (153).

$$\textbf{\textit{Daily Energy Requirement}} = \textit{Basal metabolic rate (BMR)} \times 1.2$$
$$\textbf{\textit{BMR}} = 66 + (13.7 \times \textit{weight in kg}) + (5 \times \textit{height in cm}) - (6.76 \times \textit{age in years})$$

Formula 1. Daily energy requirement calculation

After the nutrition education session and prior to the beginning of the intervention, subjects underwent the baseline dietary run-in period (~2 weeks), wherein subjects were asked to follow a healthy weight maintenance diet. During this period, subjects were asked to submit 3 day food records (2 weekdays and 1 weekend day) to monitor their calorie intake and to ensure daily energy requirement to maintain their body weight.

In order to promote a healthy weight maintenance diet, subjects were given nutrition education materials [e.g., Stop Light Guide: Healthy eating reference (**APPENDIX B**) and Calorie Fat and Carbohydrate Counter (154)]. The Stop Light Guide (modified by the Weight Management and Wellness Center of CHP) classifies foods into three groups: 1) Green (go), foods which contain low calories combined with high nutrient density, 2) Yellow (caution), foods which contain plenty of vitamins and minerals in foods but should be consumed in specific amounts for a balanced diet, and 3) Red (stop), foods which contain high calories or fat combined with low nutrient density. Subjects were asked to reduce the Red group foods and encouraged to consume the Green group and moderate amount of Yellow group foods.

All subjects were admitted to the PCTRC for baseline evaluations including anthropometric measurements (body weight, height, BMI and WC), DEXA, abdominal MRI, CRF (VO_{2peak}), and muscular strength (1-repetition maximal, 1-RM) before and after the intervention. The evaluations are described in detail in **3.2 ASSESMENTS**.

3.1.4 Randomization

After completing the baseline evaluations, 31 overweight boys were randomly assigned to 1 of 3 intervention groups: 1) aerobic exercise (AE, n = 11), 2) resistance exercise (RE, n = 13), and 3) no exercise control group (n = 7). Randomization was performed via random number generation by a staff member who was not involved in the study. During the 3-month intervention, 1 subject in the AE group dropped out of the study due to lack of interest. Of the total group, 30 subjects completed the 3-month intervention (**Figure 2**).

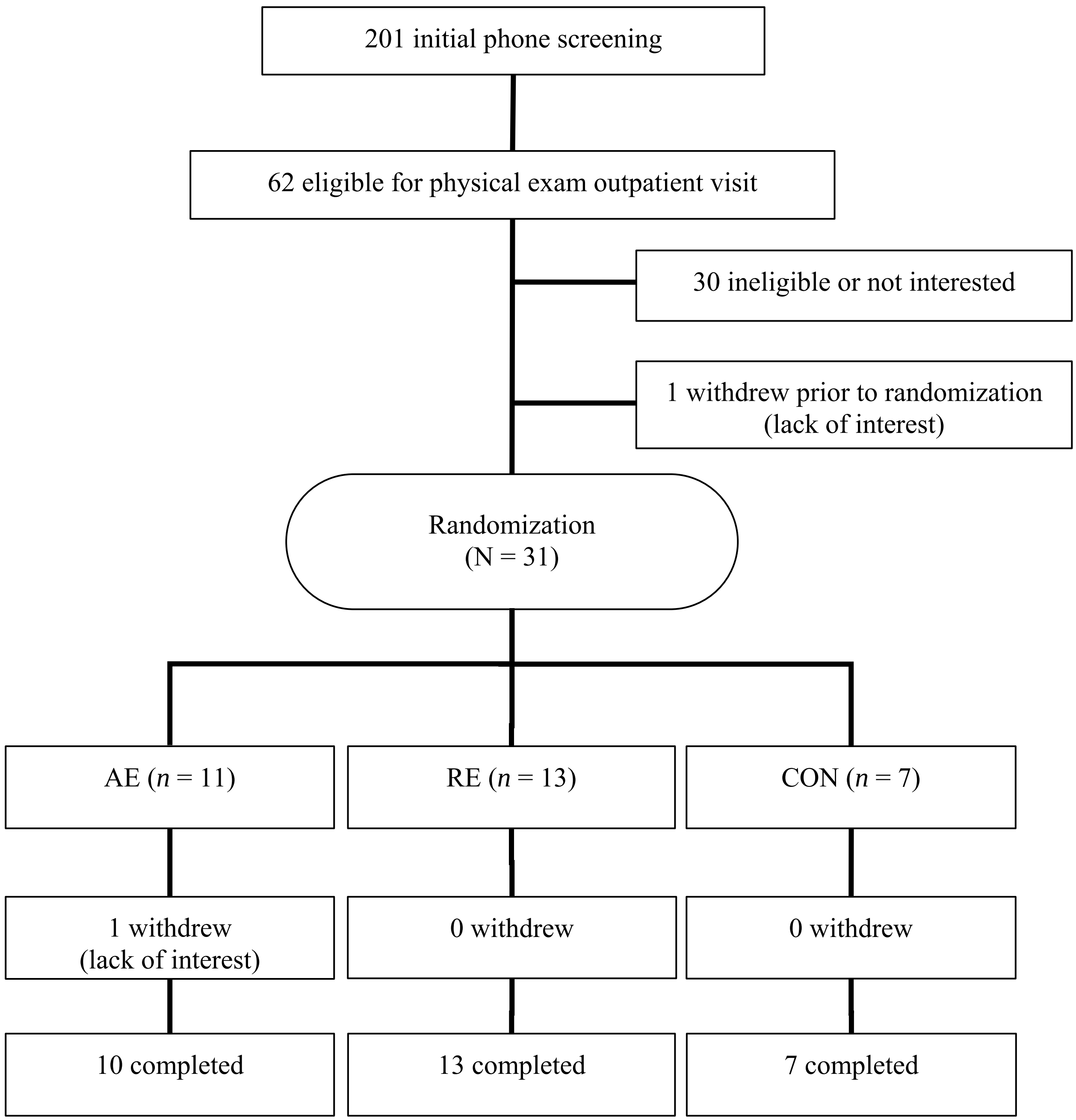


Figure 2. Flow chart

3.2 ASSESSMENTS

3.2.1 Anthropometric measurements

Body weight was measured to the nearest 0.1 kg using a calibrated medical balance-beam scale (MediChoice, BEFOUR INC, Saukville, WI). Subjects wore light clothing (e.g., shorts and t-shirt or hospital gown) during the measurement. Standing height was measured to the nearest 0.1 cm using a wall-mounted stadiometer (Heightronic Digital Stadiometer, QuickMedical, Issaquah, WA) without shoes.

WC was measured at the level of last rib, iliac crest, and umbilicus using a tension-regulated tape. External landmarks were used to identify last rib and iliac crest on both side of the body to ensure a horizontal plane of the measuring tape. The subjects were then asked to stand with legs apart (shoulder width) with both feet parallel and to fold their arms across their chest. WC was then taken at the end of a normal expiration and assessed to the nearest 0.1 cm. Two measurements were taken at each site and the average value was used for the analysis.

3.2.2 Dual-energy-X-ray absorptiometry (DEXA)

Percent body fat, total fat mass (FM), and fat free mass (FFM) were determined using a whole-body DEXA scan (Lunar iDXA, GE Healthcare, Madison, WI, USA) at the PCTRC. During the DEXA scan, subjects wore light clothing (e.g., hospital gown) without jewelry or other metal objects and were instructed to lie in a supine position with their arms placed by sides. The total scan time required for this measure was ~10 minutes. DEXA scanner was calibrated according to the manufacturer's guidelines prior to the test.

3.2.3 Measurement of abdominal AT by MRI

3.2.3.1 Abdominal MRI protocol

Abdominal AT was measured using a 3.0 Tesla MR scanner (Siemens, Magnetom TIM Trio, Germany) at the University of Pittsburgh Magnetic Resonance Research Center (MRRC). Axial images were acquired using a T1-weighted, spin-echo sequence with a 700-ms repetition time (TR), a 5.5-ms echo time (TE), a 48 cm x 36 cm field of view (FOV), and a 320 x 240 matrix during a 20-sec breath hold.

During the measurement, subjects were asked to lie in the magnet in a prone position with their arms placed straight overhead. Using the L4-L5, as the point of origin, 5 cross-sectional images (10 mm image thickness) were obtained every 40 mm, extending from 5 cm below to 15 cm above the L4-L5 (e.g., L4-L5-5 cm, L4-L5, L4-L5+5 cm, L4-L5+10 cm, L4-L5+15 cm) as shown in **Figure 3**.

The 1.5 Tesla MR scanner (General Electric Medical Systems, Milwaukee, WI) was used in two subjects who wore braces. The 1.5 Tesla images were acquired using T1-weight, spin-echo sequence with a 210-ms TR, a 17-ms TE, a 48 cm x 36 cm FOV, and a 256 x 256 matrix during a 26-sec breath hold. In our laboratory, the intra-observer variability in the analyses of 1.5 Tesla and 3.0 Tesla abdominal MRI images acquired on a same day was 3.9% for VAT and 2.1% for ASAT in two male subjects. The total time required to acquire the abdominal MRI images was 15 minutes.

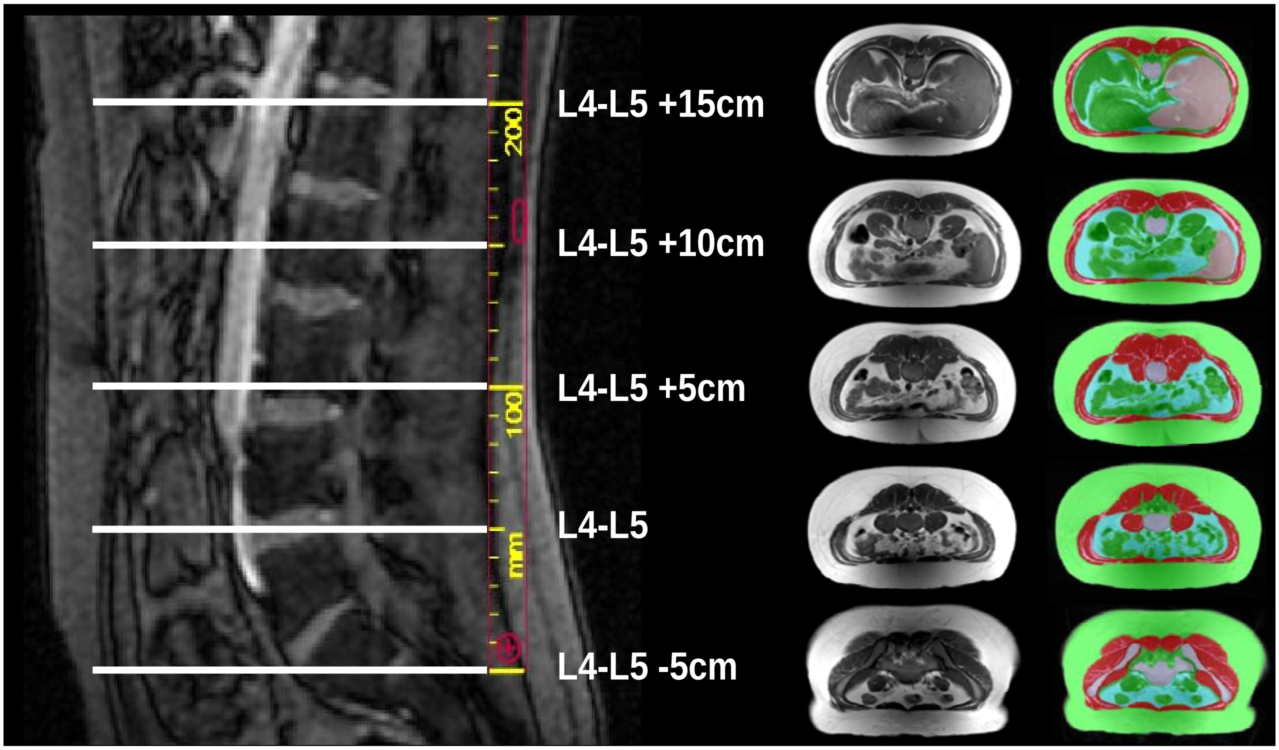


Figure 3. Abdominal MRI image Protocol

3.2.3.2 Segmentation of the MRI images

VAT and ASAT area (cm^2) of was segmented using commercially developed medical imaging software (Slice-O-Matic, Version 4.3, Tomovision, Montreal, Canada). As described previously (155-157), the surface area of VAT and ASAT was traced using different color codes. During this procedure, the color tag image was reviewed by interactive editing tools and transparency mode that allow to correct and verify the segmented result or to remove unnecessarily segmented area (e.g., bone structures or organs). An example of grey level image and segmented image are shown in **Figure 4**.

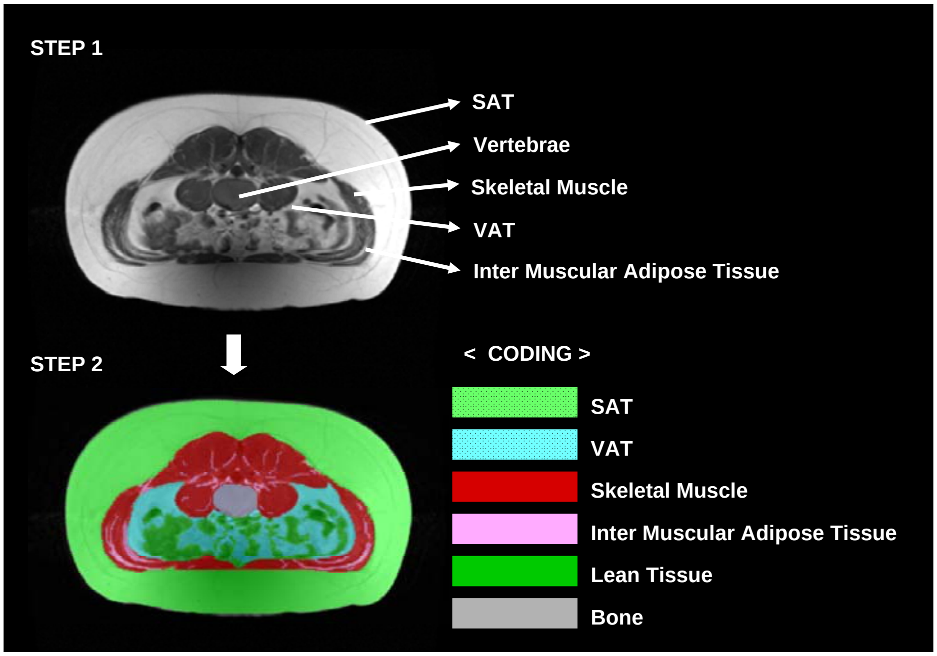


Figure 4. Segmentation of MRI image at L4-L5

The surface area (cm^2) of VAT and ASAT in each image was calculated by multiplying the total number of pixels of each AT by the surface area of individual pixel. The volume (cm^3) of VAT and ASAT in each image was calculated by multiplying the segmented area (cm^2) of each AT by the image thickness (10 mm). The estimated volume of VAT and ASAT between images was calculated using the truncated pyramid method (156) (**Formula 2**). Volume units (cm^3) were converted to mass units (kg) by multiplying the volumes by the assumed constant density for adipose tissue (0.92 kg/L) (27).

$$Volume = t\sum_{i=1}^{N} A_i + h/3\sum_{i=1}^{N}[(A_i + A_{i+1}) + \sqrt{(A_i * A_{i+1})}]$$

$\boldsymbol{A_i}$ or $\boldsymbol{A_{i+1}}$: surface area of two contiguous images
h: distance between two contiguous images
t: thickness of each image
N: the number of total images

Formula 2. Volume calculation formula (156, 158)

3.2.4 Cardiorespiratory fitness (CRF)

Cardiorespiratory fitness (VO_{2peak}) was assessed via a graded maximal treadmill test using standard open-circuit spirometry techniques (MOXUS Metabolic System, AEI Technology, Pittsburgh, PA). Prior to the test, all subjects performed warm-up for 5 minutes to familiarize with treadmill walking and to set testing treadmill speed. During the test, with a constant walking speed (3.2 ~ 3.7 mph), the grade was set at 0% for the initial 3 min and then increased by 2% for the third minute, and thereafter by 1% every minute. Heart rate (Polar Electro Oy, Kempele, Finland) was recorded every 20 seconds throughout the testing procedure. VO_{2peak} was determined as the peak level recorded at the point when the subjects reached volitional fatigue (the point at which subjects could no longer maintain the required walking speed or continue the test), and subjects met at least one of the following criteria: 1) no increase in VO_2 despite a further increase in treadmill grade, 2) the heart rate ≥ 85% of age-predicted maximal heart rate (220-age), or 3) a respiratory exchange ratio (RER) ≥ 1.1.

VO_{2peak} was measured at baseline and at the end of the 3-month intervention in all subjects. In the AE group, VO_{2peak} was also measured at the 4^{th} and 8^{th} week of the intervention to re-evaluate target heart rate and energy expenditure, which may be altered in response to aerobic exercise training.

3.2.5 Muscular strength

Upper and lower body muscular strength was assessed using a 1-repetition maximal (1-RM) test before and after the intervention in all groups. Upper-body muscular strength was assessed using chest press and latissimus pull down exercises, and lower-body muscular strength was assessed using leg press and leg extension exercises. Prior to the test, subjects were given instructions by the exercise physiologists on proper lifting techniques and test procedure, as prescribed by the American College of Sports Medicine's (ACSM) guidelines (159). Briefly, a perceived maximum weight was obtained from a subject following a warm-up of 5 to 10 repetitions at 40-60% of the perceived maximum weight (light to moderate exertion) and a subsequent test of 4 to 5 repetitions at 60-80% of their perceived maximum weight (moderate to heavy exertion). Finally, a small amount of weight (5-10 lb) was added, and a 1-RM lift was attempted. If the lift was successful, the subject rested for ~3 minutes and then attempted to lift a heavier weight (additional 5~10 lb). If the lift was not successful, a small amount of weight was removed and another 1-RM was attempted. The goal of the procedure was to determine the 1-RM within 4 maximal attempts (159).

3.3 DIETARY AND EXERCISE REGIMENS

3.3.1 Dietary regimen

Since the goal of this study was to examine the effects of exercise alone (without calorie restriction) on abdominal AT, all subjects were asked not to restrict their calorie intake but to follow a healthy weight maintenance diet (55-60% carbohydrate, 15-20% protein and 25-30% fat) which was determined during the baseline dietary run-in period.

During the 3-month intervention, all subjects were asked to submit 3 day food records (2 weekdays and 1 weekend day) to ensure the accuracy of the prescribed daily energy requirement and recommended dietary composition. The food records collected every week were reviewed by the research nutritionist and analyzed using a commercial program (Food Processor SQL, Esha Research, Salem, OR) to monitor total calorie intake (kcal/day) and the proportion (%) of carbohydrates, protein, and fat intake. If subjects tended to exceed or reduce their calorie intake compared with the prescribed daily energy requirement, or if the proportion of dietary composition was not close to the recommendation, the subjects were given dietary counseling by our research nutritionist.

3.3.2 Aerobic exercise training (AE) regimen

Subjects in the AE group underwent a 3-month supervised aerobic exercise program, 3 non-consecutive days per week for 60 minutes per session using treadmills, ellipticals, and/or bikes.

The aerobic exercise program was individually prescribed based on baseline VO_{2peak} level. For the first 2 weeks of the program, the subjects were familiarized with the equipment and exercised for 30 to 40 minutes at a heart rate equivalent to approximately 50-60% of VO_{2peak}. Starting at week 3, the subjects were exercised for 60 minutes at a heart rate equivalent to 60-75% of VO_{2peak}.

In order to ensure and maintain appropriate levels of exercise intensity during each exercise session, all subjects wore a heart rate monitor (Polar Electro Oy, Kempele, Finland), and the heart rate was recorded every 5 minutes to estimate energy expenditure during exercise session. The target heart rate (50~75% of VO_{2peak}) during exercise was determined using baseline VO_{2peak} test and re-evaluated at the 4th and 8th weeks using additional VO_{2peak} tests. Each exercise session included 5 minutes of warm-up and 5 minutes cool-down in addition to ~50 minutes of the main exercise phase. All exercise sessions were performed in the gym at CHP or the Downtown YMCA of Pittsburgh.

3.3.3 Resistance exercise training (RE) regimen

Subjects in the RE group underwent a 3-month supervised resistance exercise program, 3 non-consecutive days per week for 60 minutes per session. Each exercise session included 1) chest press, 2) lateral pull down, 3) seated row, 4) bicep extension, 5) triceps extension, 6) leg press, 7) leg extension, 8) leg flexion, 9) sit-ups, and 10) push-ups. The resistance exercise program was designed to improve muscular strength and endurance and individually prescribed based on baseline 1-RM test. For the first 2 weeks of the program, the subjects performed 1 set of 12 repetitions of each exercise with 50-60% of baseline 1-RM. During this period, emphasis was placed on proper weight lifting techniques in order to minimize the risk of injury and to familiarize with equipments rather than to elicit improvement in muscular strength and endurance. At the beginning of the 3rd week, the subjects performed 2 sets of 12 repetitions at > 60% of baseline 1-RM. Once a subject could completely perform 2 sets of 12 repetitions of each exercise using proper technique and form, then the resistance (weight stack) was gradually increased (5-10lb) to maintain adequate loads within 12 repetitions and to stimulate further strength gains.

Similar to the aerobic exercise group, each exercise session included 5 minutes of warm-up and 5 minutes of cool-down in addition to 50 minutes of the main exercise phase. All exercise sessions were performed in the gym at CHP or the Downtown YMCA of Pittsburgh. The exercise protocols for the AE and RE groups are summarized in **Table 7**.

Table 7. Exercise protocols

	AE	**RE**
	5 min of warm-up and cool down Treadmill, elliptical, bike CRF (VO_{2peak}) test at 4th and 8th week	5 min of warn-up and cool down Stretching, chest press, lateral pull down, seated row, biceps, triceps, leg press, leg extension, leg flexion, sit-ups and push-ups.
1st ~ 2nd week	30-40 min/session 50-60% of VO_{2peak} 3-5min of break at 20min	30-40 min/session, 1set of 12 reps 50-60% of baseline 1-RM 1-2 min of stretching between exercises
3rd ~ 12th week	~ 60 min/session 60-75% of VO_{2peak} 3-5min of break at 30min	~ 60 min/session , 2 set of 12 reps > 60% of baseline 1-RM 1-2 min of stretching between exercises

3.3.4 Control group

Subjects in the control group did not receive any structured exercise training during the intervention but were asked to maintain current physical activity level and to follow a healthy weight maintenance diet. Subjects were asked to return to the hospital once a month for body weight measurement and to ensure dietary intake. Further, they were given the option to receive free physical training sessions after the successful completion of post-intervention evaluations.

3.4 STATISTICAL ANALYSIS

3.4.1 Power analysis

The primary endpoint of the study was the measurement of VAT at 3 months post-intervention. The power calculation was based on a paired *t*-test of the reduction in VAT at 3 month (baseline level measured at pre-intervention) using a power analysis equation (160). In a previous study in adults (28), the 3-month aerobic exercise training alone was associated with VAT reduction of 0.56 kg (17% loss) with a standard deviation of 0.29 kg in obese men. Assuming that our overweight male adolescents would have similar reductions in VAT in response to the 3-month exercise training, we have calculated the sample size required to detect reductions in VAT at 3 levels (10%, 15% and 20%) as shown in **Table 8**.

Table 8. Power calculations

		Reductions in VAT mass		
Power	**Sample size**	**10%**	**15%**	**20%**
80%	*N*	7	3	2
90%	*N*	9	4	3
95%	*N*	11	5	3

As with any intervention, it was expected that some participants may drop out of the study during the intervention period. We expected that the dropout rate would be ~20%. Thus, a sample size of 8 subjects per group was needed to detect a reduction of 15% of VAT with a 95% power using a two-sided test and with a significance level (alpha) of 0.05.

3.4.2 Statistical analysis

A one-way analysis of variance (ANOVA) was performed to compare group differences in anthropometric, total body fat, fat free mass, abdominal MRI, CRF (VO_{2peak}), and muscular strength (1-RM) measures at baseline. A 3 x 2 repeated-measures ANOVA was performed to examine the main effects of time (pretest vs. posttest) and group (AE, RE, and Control), and interaction effects (time x group) for all dependent variables. When the interaction term (time x group) was significant ($P < 0.05$), interaction contrast was performed to locate the group differences. All statistical procedures were performed using SPSS 15.0 (SPSS, Inc., Chicago, IL).

4.0 CHAPTER FOUR

4.1 RESULTS

4.1.1 Baseline subject characteristics

Subject characteristics are shown in **Table 9**. At baseline, there were no group differences (P > 0.1) with respect to age, Tanner stage, height, body weight, BMI, WC, and total and abdominal AT. CRF (VO_{2peak}) and muscular strength (1-RM) did not differ (P > 0.1) between groups.

4.1.2 Exercise attendance, intensity, duration, and energy expenditure

A summary of exercise training sessions is shown in **Table 10**. Both exercise groups did not differ (P > 0.1) in the number of exercise sessions attended [AE: 40.7 ± 0.6 (99.0%), RE: 40.1 ± 0.7 (100%)] or in the duration of the exercise sessions (AE: 57.6 min/session, RE: 60.7 min/session). During exercise training, the mean HR attained was 155 beats/min, and the estimated energy expenditure was 740.6 ± 57.8 kcal/session in the AE group.

Table 9. Subject characteristics at baseline

	AE	RE	Control	*P* value
N (/Blacks/Whites/Others)	10 (3/7/0)	13 (7/6/0)	7 (1/5/1)	
Anthropometry				
Age (years)	15.0 ± 0.5	14.7 ± 0.4	15.0 ± 0.6	.91
Tanner Stage	4.6 ± 0.2	4.3 ± 0.3	4.9 ± 0.1	.31
Height (cm)	170.4 ± 2.6	166.1 ± 1.7	172.2 ± 2.3	.14
Weight (kg)	107.0 ± 6.4	96.8 ± 3.3	95.8 ± 5.6	.24
BMI (kg/m^2)	36.7 ± 1.9	35.0 ± 0.6	32.2 ± 1.4	.11
BMI (percentile)	98.6 ± 0.2	98.9 ± 0.2	98.0 ± 0.5	.13
WC at Last Rib (cm)	105.4 ± 3.2	102.0 ± 2.4	97.5 ± 3.7	.25
WC at Iliac Crest (cm)	114.0 ± 3.6	109.1 ± 2.5	106.4 ± 4.6	.33
WC at Umbilicus (cm)	115.2 ± 3.9	110.1 ± 2.5	106.2 ± 4.8	.26
Body Composition by DEXA				
Total body fat (%)	40.7 ± 1.3	42.1 ± 1.2	37.4 ± 2.8	.17
Fat mass (kg)	43.4 ± 3.4	40.3 ± 2.2	36.1 ± 4.1	.32
FFM (kg)	62.6 ± 3.5	54.8 ± 1.7	58.9 ± 3.2	.11
Abdominal AT by MRI				
VAT (kg)	1.6 ± 0.2	1.4 ± 0.2	1.3 ± 0.2	.46
VAT at L4L5-5 cm (cm^2)	60.1 ± 6.7	54.6 ± 7.7	48.1 ± 7.8	.59
L4L5	81.3 ± 8.9	76.6 ± 8.9	67.1 ± 9.9	.62
L4L5+5 cm	96.4 ± 12.3	83.4 ± 10.8	70.1 ± 9.8	.34
L4L5+10 cm	97.1 ± 13.0	83.8 ± 14.1	71.0 ± 11.2	.46
L4L5+15 cm	67.2 ± 9.7	49.0 ± 8.9	59.3 ± 15.3	.45
ASAT (kg)	7.7 ± 0.8	6.9 ± 0.5	5.8 ± 0.9	.26
ASAT at L4L5-5 cm (cm^2)	464.0 ± 45.5	462.7 ± 35.4	358.9 ± 54.9	.23
L4L5	496.6 ± 52.6	447.0 ± 31.0	387.9 ± 66.8	.34
L4L5+5 cm	427.1 ± 45.0	358.9 ± 30.1	321.4 ± 50.9	.22
L4L5+10 cm	329.1 ± 41.1	269.5 ± 27.0	230.7 ± 40.6	.20
L4L5+15 cm	251.5 ± 30.5	225.2 ± 23.1	184.4 ± 32.6	.31
Fitness and Muscular Strength				
VO_{2peak} (ml/kg/min)	28.8 ± 1.3	29.0 ± 1.1	31.2 ± 2.0	.49
1-RM Chest Press (lb)	131.5 ± 10.8	112.1 ± 8.6	109.6 ± 12.1	.28
1-RM Lat pull (lb)	121.3 ± 7.6	104.0 ± 5.0	109.6 ± 9.1	.18
1-RM Leg Press (lb)	155.5 ± 10.4	139.6 ± 8.1	142.9 ± 12.3	.47
1-RM Leg Extension (lb)	164.8 ± 13.2	141.7 ± 10.4	140.0 ± 16.2	.33

Values are Mean ± SE.

Table 10. Exercise training summary

	AE (*n* = 10)	RE (*n* =13)	*P* value
Total exercise sessions (Attendance rate)	40.7 ± 0.6 (99.0%)	40.1 ± 0.7 (100%)	.52
Duration per session (min)	57.6 ± 0.3	60.7 ± 1.1	.18
Exercise intensity (mean HR, beats/min)	155 ± 3	NA	
Energy expenditure (kcal/session)	740.6 ± 57.8	NA	

Values are Mean ± SE.
NA, not available

4.1.3 Self-reported food intake determined from 3-day food records

Analysis of the self-reported food intake records revealed that there was no group differences ($P > 0.1$) in total energy intake (**Table 11**). In addition, the intake of carbohydrate, protein and fat did not differ ($P > 0.1$) between groups.

Table 11. Dietary analysis during the intervention

	AE (*n* = 10)	RE (*n* = 12)	Control (*n* = 7)	*P* value
During the 3-month intervention				
Total Energy Intake (kcal/day)	1820.1 ± 107.2	1864.6 ± 135.1	1924.1 ± 211.9	.90
Carbohydrate (%)	50.3 ± 1.4	50.5 ± 0.9	50.9 ± 1.2	.58
Protein (%)	16.3 ± 0.3	16.3 ± 0.6	15.4 ± 0.9	.92
Fat (%)	33.5 ± 1.3	33.3 ± 0.9	33.6. ± 0.5	.97

Values are Mean ± SE.
Note[1]: total energy intake (kcal/day), carbohydrate, protein, and fat percentage are the average reported value throughout the 3-month intervention period.
Note[2]: dietary intake was analyzed in 12 subjects in the RE group.

4.2 EXERCISE TRAINING

4.2.1 Effects of a 3-month exercise training on anthropometric measures

Changes in anthropometric measurements are shown in **Table 12**. Body weight and BMI did not change ($P > 0.1$) in either exercise group. By contrast, there were significant increases ($P < 0.05$) in body weight (Δ 4.0 ± 0.7 kg) and BMI (Δ 1.0 ± 0.2 kg/m^2) in the control group. WC was significantly decreased ($P < 0.05$) in all measurement sites (at the levels of last rib, iliac crest, and umbilicus) in the RE group, but not in the AE group ($P > 0.1$). By contrast, WC measures in all measurement sites were significantly increased ($P < 0.05$) in the control group. The change in WC at the level of umbilicus (Δ -2.4 ± 1.7 cm) in the AE group, and at the levels of last rib (Δ -2.4 ± 0.7 cm) and umbilicus (Δ -2.3 ± 0.6 cm) in the RE group were significantly different ($P < 0.05$) from those observed in the control group.

4.2.2 Effects of a 3-month exercise training on total fat and FFM by DEXA

Compared with the control group, total body fat (kg) was significantly decreased ($P < 0.05$) in both the AE (Δ -2.3 ± 1.6 kg) and the RE group (Δ -1.4 ± 0.6 kg). Percent body fat (%) was decreased in both exercise groups (AE: Δ -1.5 ± 0.8%, RE: Δ -2.0 ± 0.5%), and the change in percent body fat (%) in the RE group only was significantly different ($P < 0.05$) from the control group. FFM was significantly increased ($P < 0.05$) in all groups, and these changes were not significantly different ($P > 0.1$) between the groups (**Table 13**).

Table 12. Changes in anthropometric measures

	AE (n = 10)			RE (n = 13)			Control (n = 7)			*P* value
	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ	Time x Group
Height (cm)	170.4 ± 2.6	171.3 ± 2.3	0.9 ± 0.5	166.1 ± 1.7	167.1 ± 1.7*	1.0 ± 0.3	172.2 ± 2.3	173.1 ± 2.2*	0.9 ± 0.3	.94
Weight (kg)	107.0 ± 6.4	106.3 ± 4.9	-0.7 ± 1.9	96.8 ± 3.3	97.1 ± 3.3	0.3 ± 0.5	95.8 ± 5.6	99.8 ± 5.6*	4.0 ± 0.7§	.05
BMI (kg/m^2)	36.7 ± 1.9	36.2 ± 1.5	-0.5 ± 0.6	35.0 ± 0.6	34.7 ± 0.7	-0.3 ± 0.2	32.2 ± 1.4	33.2 ± 1.5*	1.0 ± 0.2§	.04
BMI (percentile)	98.6 ± 0.2	98.6 ± 0.2	0.0 ± 0.2	98.9 ± 0.2	98.8 ± 0.2	- 0.1 ± 0.1	98.0 ± 0.5	98.3 ± 0.4	0.3 ± 0.2	.17
WC (cm)										
Last Rib	105.4 ± 3.2	103.9 ± 2.5	-1.4 ± 1.5	102.0 ± 2.4	99.5 ± 2.2*	-2.4 ± 0.7†	97.5 ± 3.7	99.3 ± 4.0*	1.8 ± 0.5	.04
Iliac Crest	114.0 ± 3.6	112.2 ± 2.5	-1.8 ± 1.8	109.1 ± 2.5	106.8 ± 2.4*	-2.3 ± 0.6	106.4 ± 4.6	108.0 ± 4.9*	1.6 ± 0.6	.08
Umbilicus	115.2 ± 3.9	112.8 ± 2.8	-2.4 ± 1.7†	110.1 ± 2.5	107.7 ± 2.4*	-2.3 ± 0.6†	106.2 ± 4.8	107.9 ± 4.9*	1.6 ± 0.7	.04

Table 13. Changes in total body fat and FFM as measured by DEXA

	AE (n = 10)			RE (n = 13)			Control (n = 7)			*P* value
	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ	Time x Group
Total body fat (%)	40.7 ± 1.3	39.2 ± 1.0	-1.5 ± 0.8	42.1 ± 1.2	40.1 ± 1.3*	-2.0 ± 0.5†	37.4 ± 2.8	37.8 ± 2.8	0.3 ± 0.5	.05
Total Fat (kg)	43.4 ± 3.4	41.1 ± 2.3	-2.3 ± 1.6†	40.3 ± 2.2	38.9 ± 2.3*	-1.4 ± 0.6†	36.1 ± 4.1	37.8 ± 4.3*	1.7 ± 0.4	.05
FFM (kg)	62.6 ± 3.5	63.8 ± 3.1*	1.2 ± 0.5	54.8 ± 1.7	57.4 ± 1.8*	2.6 ± 0.4	58.9 ± 3.2	60.6 ± 2.8*	1.6 ± 0.6	.10

Values are Mean ± SE.
*Significant pre-intervention vs. post-intervention differences within group ($P < 0.05$)
†Significant pre-intervention vs. post-intervention differences compared with the control group ($P < 0.05$)
§ Significant pre-intervention vs. post-intervention differences compared with the exercise groups ($P < 0.05$)

4.2.3 Effects of a 3-month exercise training on abdominal AT by MRI

4.2.3.1 VAT mass (kg) and area (cm^2)

Changes in abdominal AT mass (kg) and area (cm^2) are summarized in **Table 14**. Total VAT (kg) was significantly decreased ($P < 0.05$) in both exercise groups [AE: Δ -0.2 ± 0.1 kg (-9.7%), RE: Δ -0.2 ± 0.0 kg (-14.5%)]. By contrast, VAT (kg) was significantly increased ($P < 0.05$) in the control group [Δ 0.2 ± 0.1 kg (17.0%)] (**Figure 5a**). Compared with the control group, VAT areas (cm^2) at L4-L5-5 cm, L4-L5, L4-L5+5 cm, and L4-L5+10 cm were significantly decreased ($P < 0.05$) in both exercise groups. In addition, the reduction in VAT (cm^2) at L4-L5 was greater ($P < 0.05$) in the RE group (Δ -16.8 ± 2.5 cm^2) than in the AE group (Δ -7.8 ± 2.6 cm^2).

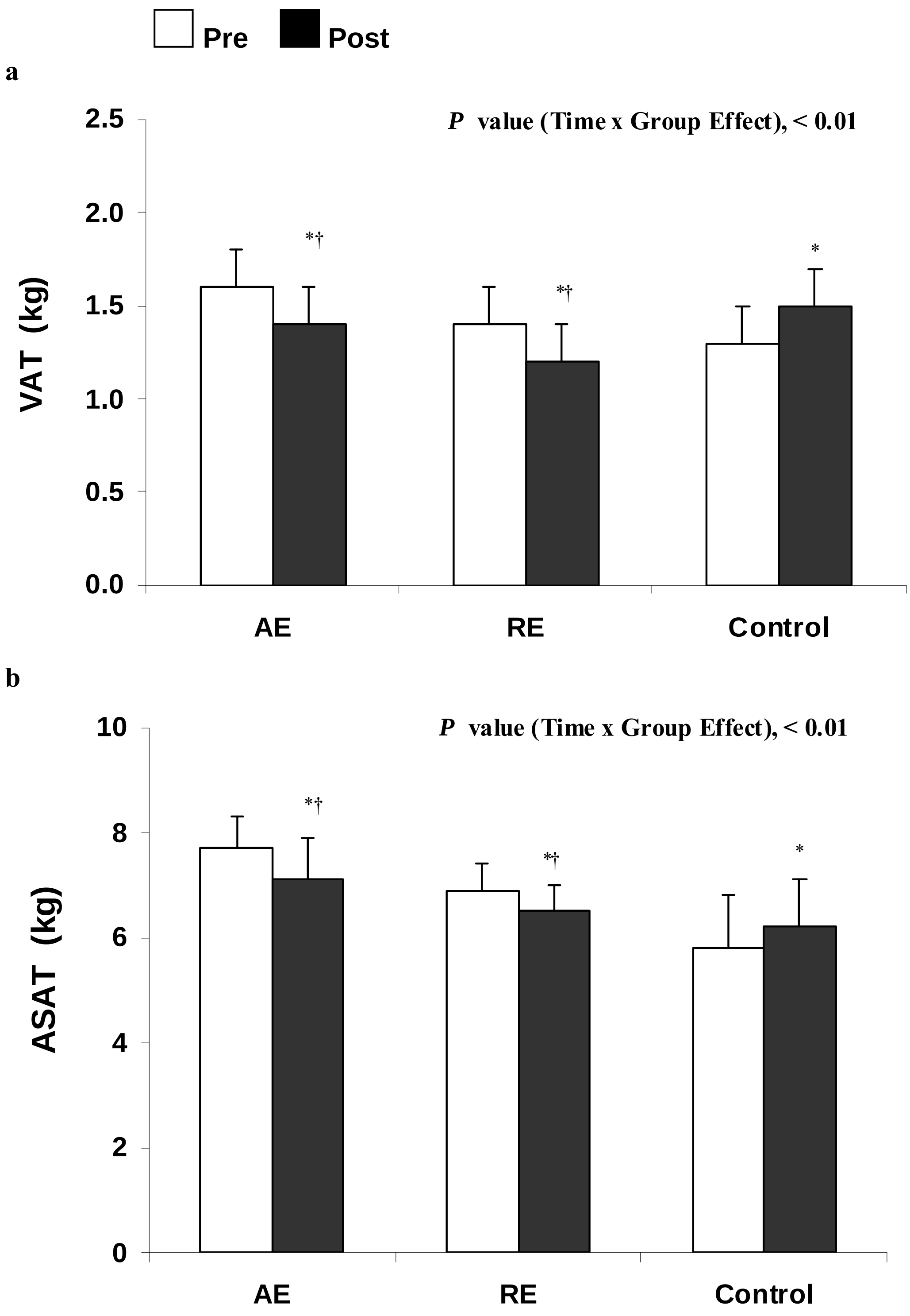
4.2.3.2 ASAT mass (kg) and area (cm^2)

Total ASAT (kg) was significantly reduced ($P < 0.05$) in both exercise groups [AE: Δ -0.7 ± 0.3 kg (-6.5%), RE: Δ -0.4 ± 0.1kg (-5.2%)]. By contrast, ASAT (kg) was significantly increased ($P < 0.05$) in the control group [Δ 0.4 ± 0.1 kg (6.2%)] (**Figure 5b**). Changes in ASAT areas (cm^2) at L4-L5-5 cm and L4-L5 in both exercise groups were significantly different ($P < 0.05$) from the control group.

Table 14. Changes in VAT and ASAT as measured by MRI

	AE (n = 10)			RE (n = 12)			Control (n = 7)			*P* value
	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ	Time x Group
AT mass (kg)										
VAT	1.6 ± 0.2	1.4 ± 0.2*	-0.2 ± 0.1†	1.4 ± 0.2	1.2 ± 0.2*	-0.2 ± 0.0†	1.3 ± 0.2	1.5 ± 0.2*	0.2 ± 0.1	< .01
ASAT	7.7 ± 0.8	7.1 ± 0.6*	-0.7 ± 0.3†	6.9 ± 0.5	6.5 ± 0.5*	-0.4 ± 0.1†	5.8 ± 0.9	6.2 ± 1.0*	0.4 ± 0.1	< .01
VAT area (cm^2)										
-5 cm	60.1 ± 6.7	50.9 ± 5.2*	-9.2 ± 3.9†	54.6 ± 7.7	42.6 ± 6.6*	-12.0 ± 3.2†	48.1 ± 7.8	53.2 ± 7.9	5.1 ± 6.4	.03
L4-L5	81.3 ± 8.9	73.5 ± 7.7*	-7.8 ± 2.6†	76.6 ± 8.9	59.8 ± 7.6*	-16.8 ± 2.5†‡	67.1 ± 9.9	77.2 ± 11.4*	10.0 ± 4.1	< .01
+5 cm	96.4 ± 12.3	89.5 ± 10.8	-6.9 ± 5.5†	83.4 ± 10.8	74.9 ± 10.9*	-8.5 ± 2.0†	70.1 ± 9.8	84.1 ± 13.4*	14.0 ± 5.4	< .01
+10 cm	97.1 ± 13.0	85.5 ± 11.3	-11.7 ± 5.6†	83.8 ± 14.1	76.3 ± 11.8	-7.6 ± 5.2†	71.0 ± 11.2	89.2 ± 16.3*	18.2 ± 6.3	< .01
+15 cm	67.2 ± 9.7	56.7 ± 9.1*	-10.5 ± 3.5	49.0 ± 8.9	45.3 ± 7.5	-3.7 ± 3.2	59.3 ± 15.3	67.2 ± 18.9	7.9 ± 9.1	.06
ASAT area (cm^2)										
-5 cm	464.0 ± 45.5	425.5 ± 40.2	-38.5 ± 17.9†	462.7 ± 35.4	416.1 ± 33.7*	-46.6 ± 11.2†	358.9 ± 54.9	385.4 ± 71.8	26.5 ± 25.0	.02
L4-L5	496.6 ± 52.6	456.5 ± 38.9	-40.1 ± 19.8†	447.0 ± 31.0	430.2 ± 30.6*	-16.8 ± 5.7†	387.9 ± 66.8	420.2 ± 70.1*	32.3 ± 7.0	< .01
+5 cm	427.1 ± 45.0	385.1 ± 31.7*	-42.0 ± 18.4†	358.9 ± 30.1	345.6 ± 27.2	-13.3 ± 8.0	321.4 ± 50.9	337.4 ± 50.8	16.0 ± 7.3	.02
+10 cm	329.1 ± 41.1	299.8 ± 34.6*	-29.3 ± 12.3†	269.5 ± 27.0	257.4 ± 23.3	-12.1 ± 7.2	230.7 ± 40.6	239.8 ± 38.0	9.1 ± 5.9	.04
+15 cm	251.5 ± 30.5	233.1 ± 24.2	-18.4 ± 10.2	225.2 ± 23.1	207.0 ± 19.8*	-18.2 ± 6.2	184.4 ± 32.6	191.1 ± 31.7	6.7 ± 3.0	.07

Values are Mean ± SE.
Note: VAT and ASAT at L4-L5 were analyzed in 13 subjects in the RE group
*Significant pre-intervention vs. post-intervention differences within group ($P < 0.05$)
†Significant pre-intervention vs. post-intervention differences compared with the control group ($P < 0.05$)
‡Significant pre-intervention vs. post-intervention differences between AE vs. RE ($P < 0.05$)



Values are Mean ± SE.

*Significant pre-intervention vs. post-intervention differences within group ($P < 0.05$)

†Significant pre-intervention vs. post-intervention differences compared with the control group ($P < 0.05$)

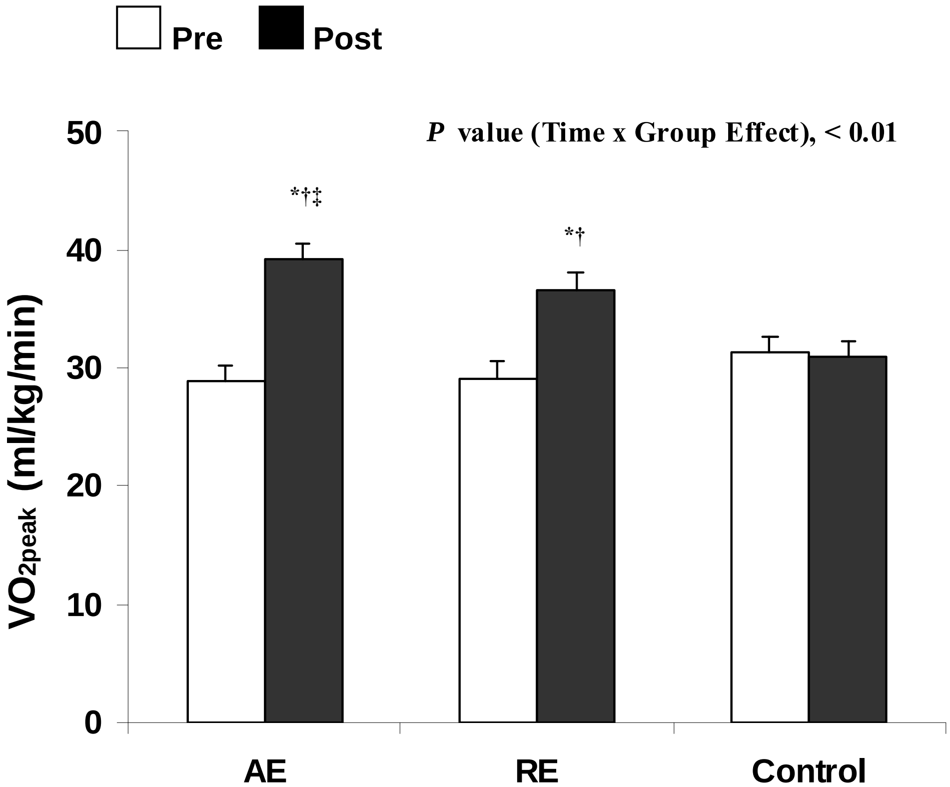
Figure 5. Effects of a 3-month exercise training on VAT and ASAT (kg)

4.2.4 Effects of a 3-month exercise training on CRF by VO_{2peak}

Compared with the control group, CRF improved significantly ($P < 0.01$) in both exercise groups [AE: Δ 10.3 ± 1.0 ml/kg/min (36.5%), RE: Δ 7.4 ± 0.8 ml/kg/min (25.8%)]. The improvement was significantly greater ($P < 0.05$) in the AE group than in the RE group (**Figure 6**). Similarly, when CRF was expressed relative to FFM (kg), the improvement remained significant ($P < 0.01$) in both exercise groups [AE: Δ 15.7 ± 1.3 ml/kg-FFM/min (32.8%), RE: Δ 10.3 ± 1.2 ml/kg-FFM/min (20.5%)], compared with the control group. The improvement was also significantly greater ($P < 0.05$) in the AE group than in the RE group (**Table 15**).

4.2.5 Effects of a 3-month exercise training on muscular strength by 1-RM

By comparison to the control and the AE group, both upper (chest press, lateral pull down) and lower body (leg press, leg extension) muscular strength was significantly increased ($P < 0.01$) in the RE group (**Table 15**). Lower body muscular strength was also significantly increased ($P < 0.05$) in the AE group.



Values are Mean ± SE
*Significant pre-intervention vs. post-intervention differences within group ($P < 0.05$)
†Significant pre-intervention vs. post-intervention differences compared with the control group ($P < 0.05$)
‡Significant pre-intervention vs. post-intervention differences between AE vs. RE ($P < 0.05$)

Figure 6. Effects of a 3-month exercise training on CRF

Table 15. Changes in CRF and muscular strength

	AE (n = 10)			RE (n = 13)			Control (n = 7)			*P* value
	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ	Time x Group
VO_{2peak} (ml/kg/min)	28.8 ± 1.3	39.1 ± 1.4*	10.3 ± 1.0†‡	29.0 ± 1.1	36.5 ± 1.5*	7.4 ± 0.8†	31.2 ± 2.0	30.9 ± 1.4	-0.3 ± 1.4	< .01
VO_{2peak} (ml/kg-FFM/min)	48.7 ± 1.7	64.4 ± 1.7*	15.7 ± 1.3†‡	50.7 ± 1.4	61.0 ± 1.8*	10.3 ± 1.2†	50.1 ± 1.9	50.0 ± 1.5	-0.1 ± 2.3	< .01
1-RM (lb)										
Chest press	131.5 ± 10.8	132.5 ± 10.3	1.0 ± 1.9	112.1 ± 8.6	145.4 ± 7.0*	33.3 ± 4.1†‡	109.6 ± 12.1	110.4 ± 10.9	0.7 ± 2.4	< .01
Lateral pull down	121.3 ± 7.6	128.0 ± 7.3	6.8 ± 3.2	104.0 ± 5.0	137.7 ± 5.5*	33.7 ± 3.7†‡	109.6 ± 9.1	111.4 ± 7.8	1.8 ± 1.6	< .01
Leg Press	155.5 ± 10.4	168.3 ± 10.5*	12.8 ± 3.0	139.6 ± 8.1	210.4 ± 23.0*	70.8 ± 19.7†‡	142.9 ± 12.3	145.7 ± 12.7	2.9 ± 2.1	< .01
Leg Extension	164.8 ± 13.2	186.3 ± 13.1*	21.5 ± 4.9†	141.7 ± 10.4	196.2 ± 9.6*	54.4 ± 5.5†‡	140.0 ± 16.2	143.6 ± 17.6	3.6 ± 2.6	< .01

Values are Mean ± SE
*Significant pre-intervention vs. post-intervention differences within group ($P < 0.05$)
†Significant pre-intervention vs. post-intervention differences compared with the control group ($P < 0.05$)
‡Significant pre-intervention vs. post-intervention differences between AE vs. RE ($P < 0.05$)

5.0 CHAPTER FIVE

5.1 DISCUSSIONS

5.1.1 Effects of a 3-month exercise training on anthropometric measures

In this study, we observed that body weight and BMI were not significantly changed in both exercise groups, whereas these were significantly increased in the control group (body weight: 4.0 ± 0.7 kg, BMI: 0.3 ± 0.2 kg/m^2) after the intervention. This finding suggest that in overweight adolescent boys, regular exercise training (3 days/week, 60 min/session) may prevent the substantial increases in body weight or BMI as seen in the control group. In the absence of changes in body weight, 3 months of resistance exercise training resulted in a significant decrease in WC (-2.3~2.4 cm) at all measurement sites in previously sedentary overweight adolescent boys. We also observed a reduction in WC (-1.4~2.4 cm) in response to aerobic exercise training, however this did not reach statistical significance. Our observation is similar to a previous study by Benson et al. (134) who reported a modest but significant reduction in WC (-0.8 cm) after an 8-week resistance exercise program without dietary restriction in boys and girls. Barbeau et al. (128) also showed that a 10-month moderate-vigorous intensity aerobic exercise program attenuated age-associated increase in WC (1.4 cm) compared with the controls (2.9 cm) in black girls (*n* = 201, 8-12 years). Others also report the benefits of circuit training (AE + RE) to decrease WC. Bell et al. (133) demonstrated a significant decrease in WC (-2.3

cm), in the absence of changes in body weight, in response to an 8-week exercise training program (3 days/week, 60 min/session) in obese boys and girls aged 9-16 years. These observations support the notion that regular exercise is beneficial to prevent increase in WC in growing children and adolescents.

In children and adolescents, WC has been increasing at a faster rate than BMI during the past two decades (14). Furthermore, evidence suggests that WC is strongly associated with VAT and cardio-metabolic risk factors, independent of BMI (18-20). Our finding that regular exercise alone reduces WC even without weight loss in overweight boys suggests the benefits of regular exercise as a strategy to decrease WC and associated improved health risk in adolescent boys.

5.1.2 Effects of a 3-month exercise training on total and abdominal AT

The primary aim of this study was to examine the effect of a 3-month AE vs. RE without calorie restriction on total and abdominal AT in overweight adolescent boys. As we hypothesized, regular exercise performed for 180 min/week, independent of exercise modality, is associated with significant reductions in total (-1.5~2.0%) and abdominal AT (VAT: -9.7~14.5%, ASAT: -5.2~6.5%) in the absence of changes in body weight in overweight pubertal boys. These findings extend the previous observation by Gutin et al. (42) who demonstrated that an 8-month aerobic exercise training program (2-5 days/week, 55-80% of VO_{2peak}) combined with lifestyle education significantly reduced body fat (-3.6%) and abdominal AT (VAT: -42.0 cm^3, ASAT: -69.7 cm^3) compared with a lifestyle education program in overweight adolescents aged 13-16 years. In a different study (126), the same group also reported significant reductions in percent body fat (-2.2%) and ASAT area (-1.0%) after a 4-month moderate intensity aerobic exercise program in overweight children aged 7-11 years. In this study (126), they noted that the age-associated increase in VAT was attenuated in the exercise training group (0.6%) compared with the controls (8.1%). Conversely, Eliakim et al. (121) reported no changes in total and abdominal AT after a 5-week endurance-type exercise training (5 days/week, ~2h/day) in adolescent girls (15-17 years). In this study (121), the subjects were varied with respect to fatness and ethnicity (Asian, White, Hispanic), which may have confounded the findings. It is also plausible that the application of skinfold technique to evaluate total body fat may have limited the ability to detect true changes in adiposity because skinfold measurements are prone to error in obese individuals (161). Furthermore, reductions in total and abdominal AT would be less likely to occur in non-obese individuals. This is supported by a recent report by van der Heijden and colleagues (148) who demonstrated significant reductions in percent body fat (-1.0%) and VAT (-9.3%) after 12 weeks of aerobic exercise (4 times/week, 30 min/session, > 70% of VO_{2peak}) in overweight Latino adolescent boys and girls, but not in their lean peers.

To date, a few studies have examined the effects of resistance exercise alone on total and abdominal AT in children and adolescents. Treuth and colleagues (43) have reported that a 5-month resistance exercise training attenuated the age-associated increase in VAT despite significant increases in total fat (1.5 kg) and ASAT (16.0 cm^2) in pre-pubertal obese girls (7-10 years). More recently, Shaibi et al. (132) have shown that in the absence of changes in body weight, a 16-week resistance exercise resulted in a significant reduction in percent body fat (-2.5%) in overweight Latino boys. Our finding that a 3-month resistance exercise training alone without calorie restriction is associated with reductions in total (-2.0%) and total abdominal AT mass (VAT: 14.5%, ASAT: 5.2%) in overweight boys extends the earlier observations (43, 132). Our study provides evidence to support the current resistance exercise recommendations (131) for children and adolescents and suggests that resistance exercise is as an effective means of reducing total and abdominal fat in adolescent boys.

Although we hypothesized that the reduction in total and abdominal AT would be greater in response to AE than RE, the changes remained similar between the groups. One possible explanation for this result is that overweight adolescent boys may be less motivated toward the aerobic forms of exercise (e.g. walking, running, or cycling) that may be uncomfortable to tolerate for prolonged exercise durations. By contrast, resistance training consisting of various exercises with brief rest between each set is not aerobically strenuous, and thus may be a more attractive form of activity (131, 132), particularly in overweight adolescents boys.

In this study, we observed that the relative change in VAT (AE: -9.7%, RE: -14.5%) was greater than that in ASAT (AE: -6.5%, RE: -5.2%) in both exercise groups. This finding agrees with previous observations in adults (25-28) demonstrating that VAT is more preferentially reduced than ASAT after regular exercise (≥ 3 days/week, ~ 30-60 min/day). The preferential reductions in VAT with regular exercise may be explained in part by the observation that visceral adipocytes are more metabolically active and sensitive to lipolytic stimulation than subcutaneous adipocytes (102, 162, 163). Catecholamines increase during exercise, and the increase is more likely to increase FFA release and lipid mobilization in visceral adipocytes than in subcutaneous adipocytes in adults (164, 165). Although further studies are needed to examine whether this remains true in adolescents, our finding provides evidence that regular exercise without calorie restriction, independent of exercise modality, is associated with preferential reductions in VAT in overweight adolescents. Given that VAT is a stronger correlate of diabetogenic and/or atherogenic risk factors in comparison to ASAT in children and adolescents (6, 39-41), our observation has clinical significance.

In addition, we observed that the absolute reduction in VAT area (cm^2) was higher at the upper regions (L4-L5+10 cm, L4-L5+15 cm) of the abdomen in the AE group but at the lower regions (L4-L5-5 cm, L4-L5) in the RE group. In adults, using multi-slice MRI techniques, a few studies (156, 166, 167) have previously examined the question of whether the reductions in VAT is consistent across the abdomen in response to regular exercise. Ross et al. (156) demonstrated that the relative reductions in VAT (cm^2) was similar across the abdominal depots in obese men, suggesting that the change in VAT could be predicted using a single-slice MRI image in the abdomen. By contrast, in obese women, the same group reported that the reductions in VAT (cm^2) were greater in the upper regions of the abdomen (L4-L5+10 cm, L4-L5+15 cm) compared with the lower regions (L4-L5-5 cm, L4-L5) (166). A recent study by Kanaley et al. (167) showed a different pattern in VAT loss in women, such that a greater VAT (cm^3) loss occurred at the L2-L3 level or lower abdominal regions in comparison with the upper abdominal regions (above L2-L3 level). These findings suggest that there is a gender difference in the VAT mobilization and perhaps, multi-slice MRI techniques may provide a better understanding of abdominal AT mobilizations in response to intervention.

In the current study, we observed that the pattern of VAT depositions (cm^2) were somewhat different between the AE vs. RE groups at baseline. In the RE group, VAT deposition was similar across the L4-L5 to L4-L5+10 cm regions, whereas in the AE group, the greatest amount of VAT was observed at L4-L5+10 cm. Thus, the greater loss of VAT area probably occurred in this depot (L4-L5+10 cm). Furthermore, it is well known that black children and adolescents have lower VAT area than their white peers (6). It is plausible that ethnic differences may have contributed to the different trend in VAT mobilization in the AE vs. RE groups, as more black boys were in the RE group (**Table 9**). Further studies are needed to provide clear explanations on this issue as the present study suggests that the mobilization of VAT may be not uniform across the abdomen in overweight boys.

With respect to FFM, Shaibi and colleagues (132) reported that in 22 overweight Latino adolescent boys, a 16-week resistance exercise without calorie restriction (2 days/week, 3sets of 8-12 reps) resulted in a substantial increase in FFM (7.4%) compared with the controls (3.4%). Similarly, McGuigan et al. (168) observed that an 8-week resistance exercise (3 days/week, 3 sets of 3-15 reps) was associated with an increase in FFM (5.3%) in overweight children aged 7-12 years. These findings are similar to the current study that FFM was increased in the RE group (4.7%) to a greater magnitude than the AE (2.4%) and control (3.1%) groups. However, the significant improvement in FFM in the RE group was not more than that in the AE or control groups. Perhaps, the FFM gains in the RE group may be insufficient to attain statistical significance compared with the control group in our study.

Together, our findings provide evidence that both exercise modalities (without calorie restriction) are beneficial to reduce total and abdominal AT in overweight adolescent boys. In particular, VAT, a strong risk factor of health outcomes in children and adolescents (39-41), was significantly decreased in response to both aerobic (-9.7%) and resistance exercise (-14.5%) in the absence of changes in body weight. Our findings highlight the importance of regular exercise as an effective strategy for the treatment of abdominal obesity and obesity-associated health risks in overweight adolescent boys.

5.1.3 Effects of a 3-month exercise training on CRF and muscular strength

As we hypothesized, a substantial improvement in CRF (VO_{2peak}) was observed in response to regular exercise training (AE: 36.5%, RE: 25.8%) in overweight adolescent boys. This substantial improvement remained similar even when expressed relative to FFM (kg) (AE: 32.8%, RE: 20.5%) in our study. Aerobic exercise has been traditionally employed as a primary exercise modality to improve CRF, and its effectiveness in youth is well demonstrated (42, 126, 169, 170). In a recent review by Baquet et al. (171), the influence of aerobic exercise on CRF in children and adolescents was evaluated from 22 controlled studies. Although there was variability in age, gender, and maturation across studies, the authors noted that aerobic exercise (≥ 3 days/week, ≥ 30 min/session, ≥ 80% of maximal HR) was associated with approximately 5-10% improvement in CRF in children and adolescents, independent of gender or pubertal status.

Gutin and colleagues (42) have shown that in overweight adolescents (13-16 years), those in the high intensity exercise training group (≥ 75% of VO_{2peak}, mean HR: 154 beats/min, ~30 min/session) achieved a significant improvement in CRF, whereas those in the moderate intensity exercise training group (55-60% of VO_{2peak}, mean HR: 138 beats/min, ~40 min/session) showed no improvement after the training program. In a recent study by Stoedefalke and colleagues (172), no improvement in CRF was observed even after a 20-week school-based aerobic exercise program (3 times/week, 25 min/session, 75% of maximal HR) in adolescents girls (13-14 years). Collectively, these observations suggest that appropriate exercise volume (e.g., frequency, intensity and duration) should be considered to induce significant improvements in CRF in adolescents. In the present study, exercise intensity (60~75% of VO_{2peak}) was individually prescribed, and those in the AE group adhered well to the exercise regimen (**Table 10**) during the intervention period, which resulted in the substantial improvement in CRF in this group.

We observed a substantial improvement in CRF (25.8%) in response to resistance exercise in overweight boys. Our findings are in contrast with the previous studies by Shaibi et al. (132) and Benson et al. (134) who reported no improvements in CRF after similar resistance exercise regimens in children and adolescents. Although further studies are necessary to clarify the mechanism by which resistance exercise training is associated with an increase in CRF in children and adolescents, conflicting results may be partially explained by the differences in exercise duration [180 min/week in the present study vs. 120 min/week in Shaibi et al. (132)] or the compliance rate to the exercise regimen [100% in the present study vs. 77% in Benson et al. (134)]. Further, the lower baseline CRF levels in our cohort compared with previous studies (132, 134) [30.0 ml/kg/min in the present study vs. 34.4-42.0 ml/kg/min] may lead to a greater improvement in CRF in our study. Some studies (173, 174) have suggested that resistance exercise training is associated with substantial improvements in endurance exercise capacity (as determined by time to exhaustion on cycle or treadmill) even without significant improvements in CRF in young male adults (18-34 years). It is plausible that those in the RE group in our study were able to perform a single bout of acute exercise (e.g., CRF test) at a greater intensity for longer duration, which may lead to the significant improvements in CRF.

Significant increases in upper (> 30%) and lower body (43-50%) muscular strength were observed in the RE group compared with the AE (upper body: ~6%, lower body: 9-14%) and control groups. This observation confirms previous reports in youth (132, 134, 175), wherein a resistance exercise training program is significantly associated with upper (~17-28%) and lower body (~27-41%) strength gains in children and adolescents. It is noteworthy that the magnitude of strength gains in upper and lower body was relatively greater in the present study than the previous observations (132, 134, 175), suggesting that our resistance exercise regimen (3 days/week, 60min/session, 2sets of 12reps) is adequate and efficacious to induce substantial muscular strength gains in overweight boys.

The substantial improvement in muscular strength can be explained by neuromuscular adaptations (e.g., motor unit activation and/or motor skill coordination) and SM hypertrophy (131, 176). In adults, it is well established that neuromuscular adaptations take place during the early stage of resistance training, while SM hypertrophy takes place in the later stage (177). In pre-pubertal children, neuromuscular adaptations are more likely to be attributed to the substantial improvements in muscular strength rather than SM hypertrophy (178, 179). By contrast, it has been suggested that training-induced SM hypertrophy could occur in post-pubertal male adolescents due to the increase in male hormone (e.g., testosterone) (131). Thus, it is plausible that the significant increases in muscular strength are a consequence of neuromuscular adaptations and concomitant SM hypertrophy in the RE group in our study. However, evidence to support this observation is lacking, since we did not account for neuromuscular adaptations to determine muscular strength gains nor measure SM change. Further studies should address this issue.

In summary, recent NHANES (1999-2002) data indicate that more than one in three adolescents aged 12-19 years (~7.5 million) are physically unfit, and these unfit adolescents are more likely to be overweight or obese and have increased risk factors than those with moderate and high fitness (116). Low CRF (37, 116, 121-123) or muscular strength (180) is strongly associated with abdominal AT and increased health risks in children and adolescents. Our observation that regular exercise training alone, independent of exercise modality, substantially improves CRF (VO_{2peak}) and muscular strength in overweight boys clearly suggests the health benefits of regular physical activity in this population.

5.2 STRENGTHS AND LIMITATIONS

The strengths of this study warrant mention. Our study extends previous observations by employing a multiple-slice MRI technique to examine abdominal AT mobilization in response to regular exercise. Further, high attendance rates in the AE (99.0%) and RE (100%) groups suggest that our exercise regimen is feasible and could be implemented in school settings. Indeed, no subjects in the exercise groups were injured during the 3-month intervention, suggesting that our exercise prescription is an adequate and enjoyable for overweight adolescent boys.

Although the present study was very successfully implemented, limitations should be also acknowledged. The potential limitation in this study is the small sample size. Although the power and sample size were calculated to detect a reduction of 15% in VAT with 95% power at a significance level of 0.05, the calculation was based on previous findings in an adult study that was not designed to examine the effects of exercise modality (AE vs. RE) on total and abdominal AT. Thus, the small sample size may have limited the ability to detect statistical significance on measurement variables within or between groups. Further studies should include a larger sample size to detect the statistical significances with higher power levels.

Secondly, we only included overweight adolescent boys (BMI $\geq$ 95th percentile) to eliminate confounding effects of gender. Thus, the findings from this study can be only generalized to overweight black and white male adolescents. Further studies are required to explore whether our observations remain true in different pediatric populations (e.g., lean adolescent boys, lean or overweight adolescent girls, and other ethnicity).

With respect to dietary intake, the average amount of total energy intake (kcal/day), as determined by self-reported 3-day food records over the intervention, was only approximately 80% of the prescribed daily energy requirement in the present study. If this was true, a significant weight loss may have occurred due to negative energy balance. It is very well-known that overweight children and adolescents tend to underreport their food intake compared with their lean counterparts (181, 182). Doubly labeled water (DLW) technique has been used as a criterion method for validating the accuracy of self-reported dietary intake or measuring energy expenditure (183, 184). Thus, further studies should utilize this technique for accurate measure of energy intake or expenditure in daily living, particularly in overweight children and adolescents. However, DLW method is limited due to high cost or feasibility for analysis, suggesting that additional techniques for easy, inexpensive, and accurate assessments of dietary intake should be also considered in children and adolescents.

Another limitation is that a subsequent CRF test was assessed at 4th and 8th week to re-evaluate target HR and energy expenditure in the AE group only. These repeated test exposure may influence the changes in CRF in this group. Lastly, our study examined the short-term effects of exercise training (AE vs. RE) on total and abdominal AT in overweight adolescent boys. Further studies should address whether exercise training with a longer intervention period or a combination of exercise modes (e.g., AE + RE) will result in different findings in this age group. In addition, we did not examine whether the reductions in total and abdominal AT induce improvements in health outcomes. Further studies should also address on this issue in overweight adolescent boys.

5.3 CONCLUSION

In conclusion, 3 months of regular exercise training (60 min/day, 3 times/week) without calorie restriction, independent of exercise modality, is associated with significant reductions in WC, total and abdominal AT and improvements in CRF and muscular strength in the absence of changes in body weight in previously sedentary, overweight boys. Our observations suggest that regular exercise alone is an effective treatment strategy for the treatment of obesity, in particular abdominal obesity, in overweight adolescent boys.

In adolescents, the increases in obesity have been accompanied by declines in physical activity levels over the last two decades. Given that both abdominal obesity and physical inactivity are strongly associated with many health outcomes, our findings have clinical implication that could be implemented in public health settings to combat the current epidemic of childhood obesity and abdominal obesity in children and adolescents.

APPENDIX A

[EXERCISE TRAINING AND MEASUREMENT FORMS]

AEROBIC EXERCISE DATA FORM

RESISTANCE EXERCISE DATA FORM

CARDIORESPIRATORY FITNESS TEST

MUSCULAR STRENGTH TEST

WAIST CIRCUMFERENCE MEASUREMENT

MY PERSONAL FOOD RECORD

AEROBIC EXERCISE DATA FORM Week: ____________________

Name (ID): ____________________________________ Age: _____________ Sex: male / female

Height (cm): ____________________________ Max HR (bpm): _____________

	Mon Tue Wed Thu Fri Sat				Mon Tue Wed Thu Fri Sat				Mon Tue Wed Thu Fri Sat				Mon Tue Wed Thu Fri Sat			
	Date: / /				Date: / /				Date: / /				Date: / /			
	Time (min)	Speed (mph)	Grade (%)	HR (bpm)	Time (min)	Speed (mph)	Grade (%)	HR (bpm)	Time (min)	Speed (mph)	Grade (%)	HR (bpm)	Time (min)	Speed (mph)	Grade (%)	HR (bpm)
Warm-Up	Resting	-	-		Resting	-	-		Resting	-	-		Resting	-	-	
	0~5				0~5				0~5				0~5			
	5~10				5~10				5~10				5~10			
Aerobic Exercise	10~15				10~15				10~15				10~15			
	15~20				15~20				15~20				15~20			
	20~25				20~25				20~25				20~25			
	25~30				25~30				25~30				25~30			
	30~35				30~35				30~35				30~35			
	35~40				35~40				35~40				35~40			
	40~45				40~45				40~45				40~45			
	45~50				45~50				45~50				45~50			
Cool-Down	50~55				50~55				50~55				50~55			
	55~60				55~60				55~60				55~60			
Comments:	Body Weight (kg):				Body Weight(kg):				Body Weight(kg):				Body Weight(kg):			
	Time: Min:				Time: Min:				Time: Min:				Time: Min:			

RESISTANCE EXERCISE DATA FORM

Week: ____________

Name (ID): ________________________ Age: ____________ Sex: male / female

Height (cm): ________________________

	1 RM (lb)	Mon Tue Wed Thu Fri Sat Date: / / Weight (lb) / Repetition (8~12)			Mon Tue Wed Thu Fri Sat Date: / / Weight (lb) / Repetition (8~12)			Mon Tue Wed Thu Fri Sat Date: / / Weight (lb) / Repetition (8~12)			Mon Tue Wed Thu Fri Sat Date: / / Weight (lb) / Repetition (8~12)		
Warm-Up		1^{st} set	2^{nd} set	3^{rd} set	1^{st} set	2^{nd} set	3^{rd} set	1^{st} set	2^{nd} set	3^{rd} set	1^{st} set	2^{nd} set	3^{rd} set
1. Leg Press													
2. Leg Extension													
3. Leg Flexion													
4. Chest Press													
5. Lat Pull-Down													
6. Seated Row													
7. Bicep Curl													
8. Triceps Extension													
9. Sit-Up													
10. Push-UP													
Comments:		Body Weight (kg):			Body Weight (kg):			Body Weight (kg):			Body Weight (kg):		
		Time: Min:			Time: Min:			Time: Min:			Time: Min:		

CARDIORESPIRATORY FITNESS TEST (VO_2peak Test)

Name: ______________________ Test Date: ______________________

ID: ______________________ Gender: male / female

Age: ______________________ Test: pre / post

Weight (kg): ______________________ Height (cm): ______________________

Age-adjusted Max HR (bpm): 220 – age = ____________ Speed (mph): ______________________

Time (min)	Grade (%)	HR (bpm)	Time (min)	Grade (%)	HR (bpm)
00:00	**0**		10:20		
0:20			10:40		
0:40			11:00	**10**	
1:00			11:20		
1:20			11:40		
1:40			12:00	**11**	
2:00			12:20		
2:20			12:40		
2:40			13:00	**12**	
3:00	**2**		13:20		
3:20			13:40		
3:40			14:00	**13**	
4:00	**3**		14:20		
4:20			14:40		
4:40			15:00	**14**	
5:00	**4**		15:20		
5:20			15:40		
5:40			16:00	**15**	
6:00	**5**		16:20		
6:20			16:40		
6:40			17:00	**16**	
7:00	**6**		17:20		
7:20			17:40		
7:40			18:00	**17**	
8:00	**7**		18:20		
8:20			18:40		
8:40			19:00	**18**	
9:00	**8**		19:20		
9:20			19:40		
9:40			20:00	**19**	
10:00	**9**				

Cool-Down	1:00	2:00	3:00	4:00	5:00
HR (bpm)					

Max HR (bpm): ______________________

Max VO^2 (ml/kg/min): ______________________ Staff: __________

MUSCULAR STRENGTH TEST (ONE REPETITION MAXIMAL, 1-RM)

Name:	______________	Test Date:	______________
ID:	______________	Gender	male / female
Age:	______________	Test:	pre / post
Weight (kg):	______________	Height (cm):	______________

	Warm-Up		Trial 1	Trial 2	Trial 3	1 RM
Upper Body	40-60%	60-80%	1 RM	1 RM	1 RM	
1. Chest Press						
2. Lat Pull-Down						

Lower Body	40-60%	60-80%	1 RM	1 RM	1 RM	
1. Leg Press						
2. Leg Extension						
Comments:						

Staff: ___________

WAIST CIRCUMFRENT MEASUREMENT

Name: ________________ Test Date: ________________

ID: ________________ Gender: male / female

Age: ________________ Test: pre / post

Weight (kg): ________________ Height (cm): ________________

Waist Circumference (cm)	1^{st}	2^{nd}	Average
1. Last Rib			
2. Iliac Crest			
3. Umbilicus			

Staff: ___________

MY PERSONAL FOOD RECORD:

NAME: ______________________ Target Calories: ______________________

DATE: ______________________ Weight: ______________________

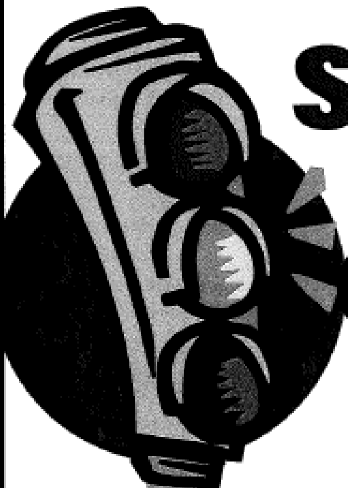
MEAL	AMOUNT	FOOD	CALORIES	FAT (g)
BREAKFAST				
		Subtotal:		
LUNCH				
		Subtotal:		
DINNER				
		Subtotal:		
SNACKS				
		Subtotal:		
ASSESSMENT		Total:		
		Fat:	Kcal	%
		Carbohydrate:	Kcal	%
		Protein:	kcal	%

GOALS	

APPENDIX B

[STOP LIGHT GUIDE: HEALTHY EATING REFERENCE]

STOP LIGHT GUIDE



Healthy Eating Reference

Children's
Hospital of Pittsburgh

Children's
Hospital of Pittsburgh
Weight Management
and Wellness Center

Your Name

Your Nutritionist

Guidelines for estimating portion sizes

palm = 3 oz.
Example: a cooked serving of meat

handful = 1 or 2 oz. snackfood
Example: 1 oz. nuts = 1 handful; 2 oz. pretzels = 2 handfuls

thumb = 1 oz.
Example: a piece of cheese

fist = 1 cup
Example: two servings of pasta or oatmeal

thumb tip = 1 teaspoon
Example: a serving of mayonnaise or margarine

GREEN – GO
Low-Calorie Foods

One serving = 1/2 cup of cooked vegetables or vegetable juice
One serving = 1 cup of raw vegetables

VEGETABLES	Calories
Artichokes	30
Asparagus (cooked)	25
Bean sprouts	15
Beans (green or wax beans)	20
Beets	25
Broccoli (raw)	25
Brussels sprouts	30
Cabbage	20
Carrots	35
Cauliflower	20
Celery	15
Cucumbers	14
Eggplant	14
Greens (endive, kale, etc.)	25
Lettuce	7
Mushrooms	20
Okra	30
Onions (raw)	60
Parsley	10
Peppers (raw)	40
Radishes (raw)	20
Sauerkraut Ⓢ	13
Spinach (cooked)	20
Squash (summer, winter, acorn squash)	15
Tomatoes (raw or cooked)	35
Tossed salad	varies
Vegetable juice (vegetable, V-8®) Ⓢ	25
Water chestnuts	
Zucchini	15

SWEET SUBSTITUTES	Calories
Gelatin, sugar-free	<20
Gum, sugar-free	<20
Popsicles®, sugar-free no more than 3 per day	<20

BEVERAGES*

- Club soda
- Flavored water
- Mineral or spring water
- Sugar-free drink mixes, iced tea or pop

* containing less than 1 calorie per ounce

SUGAR SUBSTITUTES*

- Saccharin (Sweet 'n Low®)
- Aspartame (Equal® or Nutrasweet®)
- Acesulfame K (Sweet One®)
- Sucralose (Splenda®)

* containing less than 1 calorie per ounce

Ⓢ Sodium = 400 mg or more per serving

GREEN – GO
Low-Calorie Foods

CONDIMENTS & MISC.

* fewer than 25 calories per serving

- All herbs and spices
- Basil
- Bouillon or broth without fa Ⓢ
- Butter- or sour cream-flavored seasonings (Butter Buds®, I Can't Believe It's Not Butter® spray, Molly McButter®)
- Cooking spray (PAM®)
- Celery seeds
- Cinnamon
- Chili powder
- Chives
- Curry
- Dill
- Flavoring extracts (almond, butter, lemon, peppermint, vanilla, etc.)
- Garlic salt or garlic powder
- Horseradish
- Hot pepper sauce
- Lemon
- Lemon juice
- Lemon pepper
- Lime
- Lime juice
- Mint
- Mustard
- Onion powder
- Oregano
- Paprika
- Pepper
- Pickles (dill, unsweetened) Ⓢ
- Pimiento
- Salad dressing (low-calorie*) Ⓢ
- Soy sauce Ⓢ
- Taco sauce
- Vinegar
- Worcestershire sauce

Ⓢ Sodium = 400 mg or more per serving

YELLOW – CAUTION

To be used in specific amounts necessary for a well-balanced diet

PROTEIN FOODS

Meat, Fish and Poultry	Calories
One serving = 1oz, limit to 3oz, per day.	
Beef Cuts: round, sirloin, chuck (limit to 3 times per week)	165
Fish: tuna and other canned fish packed in water	105
Lamb Cuts: leg, shoulder, chop	165
Pork, Cured: ham, Canadian bacon	165
Pork Cuts: center cut, tenderloin	135
Poultry: chicken, turkey (without skin)	90
Veal Cuts: all but breast (limit to 3 times per week)	180

Baked, broiled, boiled, roasted, grilled or microwaved. Avoid fried foods and heavy gravies.

Deli Meats (Reduced Fat)	
One serving = 1oz, limit to 3oz, per day.	
Chicken or turkey breast	35
Hot dogs, reduced fat Ⓢ	40
Lean cold cuts	35
Lean ham	35
Lean roast beef	35

Cheese (Reduced fat or low-fat; look for 3–5g of fat per serving)	
One serving = 1oz, limit to 3oz, per day.	
Cottage cheese (low-fat, 4oz)	102
Cheese (American, cheddar, string, Swiss, mozzarella, Parmesan, provolone, Romano, etc.)	55
Low-fat cream cheese (2 Tbsp.)	66

Eggs	Calories
One serving = 1 egg cooked or poached in water, no more than 2 per day.	75
One serving = 1/4 cup, scrambled, no more than 1/2 cup per day.	
All eggs: poached, soft-boiled, hard-boiled, fried eggs, omelets or scrambled in non-stick pan or with spray oil coating (PAM®).	
If you use egg whites only, you can double the amounts used for the same amount of calories.	

Legumes	
One serving: 1/2 cup; count as 1 oz protein + 1 starch	
Dried beans, cooked (pinto, kidney, navy, white, split, black-eyed)	115
Garbanzo (chick peas)	134
Lentils	115
Dried peas, cooked	60
One serving: 1 cup; count as 1 oz protein + 1 starch	
Bean soup	160
Lentil soup	150
Lima beans	160

Peanut butter	
One serving = 1 Tbsp; also count 5g of fat	95

Ⓢ Sodium = 400 mg or more per serving

YELLOW – CAUTION

To be used in specific amounts necessary for a well-balanced diet

MILK & DAIRY

Milk	Calories
One serving = 1 cup = 8 oz.	
Fat-free or skim milk	90
1 percent milk	100
2 percent milk	120
Buttermilk, low-fat	120
Sugar-free hot cocoa	110

Yogurt	
4 oz. low-fat fruit yogurt	120
8 oz. sugar-free, low-fat fruit yogurt	130

Milk Desserts	
Fat-free pudding (1/2 cup)	80
Low-fat or sugar-free frozen bars (example: Fudgesicles®)	45
Low-fat ice cream (1/2 cup)	90
Low- or non-fat frozen yogurt (1/2 cup)	120
Sherbet (1/2 cup)	160
Sugar-free fat free pudding (1/2 cup)	35

STARCHES

Breads	Calories
One serving =	80–100
Bagel (half)	
Biscuit (one)	
Bread, regular (one slice)	
Bread stick (one)	
Bun, regular (half a hotdog or hamburger bun)	
Croutons (no fat added)	
English muffin (half)	
Pancake (reduced fat 4″ square)	
Pita (half)	
Dinner roll (small)	
Taco shell (2 shells)	
Tortilla shell (1 flour shell)	
Waffle (reduced fat 4″ square)	

Cereals	
Cooked (unsweetened): One serving = 1/2 cup	80
Low-fat granola: One serving = 1/2 cup	170
Plain (not sugar-coated) Cheerios®, Rice Krispies®: One serving = 3/4 cup	80
Sweetened cereals: One serving = 1/2 cup	80

YELLOW – CAUTION

To be used in specific amounts necessary for a well-balanced diet

STARCHES (cont'd)

Pasta & Rice	Calories
One serving = 1/2 cup, cooked	
Rice (white, brown, wild or Spanish rice)	100
Pasta (spaghetti, bow tie pasta, rotini, macaroni, egg noodles, etc.	110
One serving = 1/2 cup	
Pasta with plain tomato sauce Ⓢ or lean meat sauce/meatballs (count as 1 starch + 1 oz protein)	200
Beans and rice (count as 1 starch + 1oz protein)	115

Crackers/Snacks	
One serving =	80–100
Cheese snack crackers	
Goldfish®	
Graham crackers	
Pretzels	
Ritz®	
Saltines	
Wheat Thins®	

Soups	
One serving = 1 cup	
Beef noodle or vegetable	170
Chicken (gumbo, noodle, rice, vegetable)	115
Minestrone	125
Turkey noodle or vegetable	135
Tomato (plain or tomato rice)	135
Vegetable	120

Desserts/Cookies	Calories
One serving =	80–100
Angel or sponge cake	
Cookies: Animal Crackers, ginger snaps, vanilla wafers	
Popcorn: microwave light pop corn or popped without butter	

Starchy Vegetables	
One serving = 1/2 cup	
Corn	65
Mixed vegetables	40
Potatoes, white: baked, boiled, mashed (no fat added)	80
Sweet potatoes	80
Yams	80

FRUITS

One serving = 1/2 cup	
Any fresh, frozen or canned fruit in light syrup	varies
One serving = 1/2 cup	
Fruit juice (limit to 1 cup 8 oz. per day)	60

Ⓢ Sodium = 400 mg or more per serving

YELLOW – CAUTION

To be used in specific amounts necessary for a well-balanced diet

FATS & OILS

Butter/margarine/oil/ mayonnaise	Calories
- Regular (5 g of fat = 1 tsp.)	35
- Light (5 g of fat = 1 Tbsp.)	50
Salad dressing	
- Regular (5 g of fat = 1 Tbsp.)	65
- Light (5 g of fat = 2 Tbsp.)	35
Sour cream	
- Regular (5 g of fat = 1 Tbsp) Ⓢ	25
- Light (5 g of fat = 2 Tbsp) Ⓢ	40
Cream cheese	
- Regular (5 g of fat = 1 Tbsp.)	50
- Light (5 g of fat = 2 Tbsp.)	70
Olives	
- (5 g of fat = 8 olives) Ⓢ	40
Low Fat Gravy	
5 g of fat = 1/4 cup	30

NUTS

Almonds (5 g of fat = 8 almonds)	50
Cashews (5 g of fat = 5 nuts)	50
Peanuts (5 g of fat = 10 peanuts)	45
Pecans (5 g of fat = 5 halves)	50
Mixed nuts, 50 % peanuts (5 g of fat = 6 nuts)	45

MAIN DISH CASSEROLES

Beef stew with lean beef	320
Chili with lean meat	330
Frozen dinners (Budget Gourmet Lite®, Lean Cuisine®, Healthy Choice®, Weight Watchers Smart Ones®) Ⓢ	210
Lean stir-fry	300
Meatloaf with lean meat	300
Pizza with low-fat cheese (vegetable toppings, if desired)	170
Tacos (lean beef or chicken)	150

CONDIMENTS & MISC.

Use in moderation:	Calories
Chili sauce – 1 Tbsp	20
Jellies and jams – 1 Tbsp	50
Imitation bacon bits	
Ketchup – 1 Tbsp	15
Light pancake syrup – 1 Tbsp (can be butter-flavored syrup)	25
Salsa – 1 Tbsp	10

FAST FOODS Ⓢ

Baked potato, plain (topping on the side)	270
Chili	275
Grilled chicken breast	120
Grilled chicken salad with low-fat dressing	220
Plain roast beef sandwich	220
"Small" hamburger (any fast-food chain)	280
Salad bars (use low-calorie salad dressing)	varies
Small steaks and chopped steaks	160
Submarine sandwich, low-fat (fewer than 6 grams fat per serving)	330
Small soft-serve ice cream	222
Tacos (chicken or beef)	210
Taco salads with low-calorie dressing	380
Turkey breast sandwich	210

Ⓢ Sodium = 400 mg or more per serving

RED – STOP

High in Calories – Choose no more than one or two foods weekly from red foods listed

PROTEIN FOODS

Meat/Fish/Poultry (3 oz. unless noted)	Calories
Beef: ground chuck, Delmonico, Salisbury Steak, prime rib	225
Fish: fried fish, fried seafood, canned fish in oil	200
High-fat lunch meats: bologna, braunschweiger, chipped ham, olive loaf, pepperoni, salami (1 oz)	100
Hot dog – regular (S)	145
– reduced fat	110
Pork: bacons, kielbasa, spare ribs, sausage	330
Poultry: fried chicken	220
Veal: fried cutlet	200
Eggs	
Eggs (2) fried in butter or fat	275
Miscellaneous	
ALL FRIED OR GRAVIED ITEMS!	

(S) Sodium = 400 mg or more per serving

MILK & DAIRY

Milk	Calories
Cappuccino from mix (8 oz)	100
Cream (whipping, heavy or half-and-half) (1 Tbsp)	40
Egg nog (1/2 c.)	160
Hot cocoa (1 cup)	225
Shakes (small)	405
Whole milk (1 cup)	150
Yogurt	
Whole-milk yogurt (1 cup)	180
Yogurt with sprinkles (1/2 cup)	85
Cheese (S)	
Cheese sauce (2 Tbsp)	100
Nacho sauce (2 Tbsp)	100
Milk Desserts	
Ice cream (1/2 cup)	170
Ice cream desserts	varies
Ice cream novelties	varies

Warning! These are high-calorie foods! Keep servings as small as possible!

RED – STOP

High in Calories – Choose no more than one or two foods daily from red foods listed

BREADS & STARCHES

Breads	Calories
Donuts	200
French toast sticks	400
Muffin, large	400
Sweet breads (date and nut, banana, cinnamon and raisin, etc.)	varies
ex: 1 slice banana nut bread	230
Sweet rolls	816
Cereals	
Granola-type cereals (1/2 cup) (unless low-fat)	300
Side Dishes	
Egg rolls	150
Fettuccini Alfredo (1/2 cup)	184
Fried Rice (1/2 cup)	225
Noodles with cream sauces	varies
Vegetables	
Vegetables in white, cream or cheese sauce	varies
Potatoes: au gratin potatoes; baked potatoes with sour cream, butter or margarine; french fries; hash browns; mashed potatoes with gravy or butter; Tater Tots®; potato salad; scalloped potatoes	varies
Snacks (S)	
Frozen onion rings (3 pieces)	190
Cheese curls, puffs or twists	153
Combos® (1 bag = 1.7 oz.)	240
Corn chips	160
Cracker Jacks® (1/2 c.)	120
Doritos® (11 chips)	140
Popcorn, buttered (1 cup)	40
Pork rinds	94
Potato chips (20 chips)	150
Potato sticks (1/2 cup)	94

Cookies	Calories
Brownies	112
Cookies (chocolate chip, peanut butter, cream filled, etc.)	varies
ex: Chips Ahoy	120
Granola bars (except low-fat)	
Soups (S) (1 cup)	
Vegetables in white, cream or cheese sauce	>200
Cheese soups	>200
Cream soups	>200
Oriental noodle soups (1/2 block) (Ramen® for example)	190
Desserts	varies
Cake with icing	235
Cupcakes	250
Hostess® cakes (Twinkies®, HoHos®, Lil' Debbie® snacks, etc.)	180
Cream puffs or eclairs	300
Fruit cake	150
Gingerbread	265
Gelatin, regular (1 cup)	150
Pies	>300
Pop-Tarts®	>200

(S) Sodium = 400 mg or more per serving

RED – STOP

High in Calories – Choose no more than one or two foods weekly from red foods listed

FATS & OILS

	Calories
Nuts (1 oz)	170
Olives (1 oz)	45
Sauces and gravies (all) (1/2 c.)	65
Seeds (1 oz)	165

CANDY

All candy (including diet and low-fat candy)	varies

MAIN DISH CASSEROLES Ⓢ

Per serving	Calories
Chicken or tuna noodle casserole	180
Chicken à la King	370
Easy Mac®	240
Hot Pocket®	>300
Hot Subs®	varies
Lasagna	>250
Macaroni and cheese	200
Pizza with high-fat toppings such as pepperoni, sausage, olives and/or pizza made with high-set crust	300
Pot pies	450
TV dinners, regular size	varies

Ⓢ Sodium = 400 mg or more per serving

Warning! Keep servings as small as possible!

RED – STOP

High in Calories – Choose no more than one food weekly from fast foods

No Super Sizing!

FAST FOODS Ⓢ

	Calories
Arby's®	
French fries (regular size)	377
Sandwiches (except regular roast beef)	>450
Shakes (regular size)	500
Baskin-Robbins®	
Ice cream, all flavors	varies
Sugar- and fat-free ice cream can count as "yellow light" dairy foods.	
Burger King®	
Bacon cheeseburger	390
French fries (regular size)	364
Shakes (regular size)	600
Specialty sandwiches	varies
Whopper® (w/o cheese)	700
Dunkin' Donuts®	
All donuts	varies
KFC®	
Everything except roasted chicken without skin	varies
Long John Silver's®	
Everything except baked or broiled fish without sauces	varies
Pizzerias	
Deep dish pizza	>300
Stuffed crust pizza	>350
Bread sticks (1 stick)	150
Order in or delivery	

	Calories
McDonald's®	
Big Mac®	560
Chicken McNuggets® (6 piece)	255
Egg McMuffin®	290
Filet-o-Fish®	400
French fries (medium)	354
Fruit pie	250
Hotcakes (in butter)	600
Quarter Pounder® (w/o cheese)	420
Steak Houses	
French fries	475
Large steaks (more than four ounces pre-cooked)	>400
Most desserts	varies
Wendy's®	
All burgers (except single)	varies
Breaded chicken	410
Frostys™ (small)	328
French fries (regular size)	440
Sandwiches (grilled chicken is a good choice)	varies
Stuffed potatoes	>320
Salads with regular dressings	varies
Taco Bell®	
Chalupas	400
Chimichangas	815
Enchiladas	210
Nachos with cheese	320

Ⓢ Sodium = 400 mg or more per serving

BC/MT 06-317 PDF

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